



July 13, 2017
Gasco Sediments Cleanup Action



Pre-Remedial Basis of Design Technical Evaluations Work Plan

Prepared for U.S. Environmental Protection Agency, Region 10

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Prepared for

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Region 10
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ABBREVIATIONS

ACES	Automated Coastal Engineering System
AOC	Administrative Settlement Agreement and Order on Consent
ARAR	Applicable or Relevant and Appropriate Requirement
BMP	Best Management Practice
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
CRD	Columbia River Datum
CVOC	chlorinated volatile organic compound
CWA	Clean Water Act
cy	cubic yard
DEQ	Oregon Department of Environmental Quality
DSAY	discounted service-acre years
DSL	Oregon Department of State Lands
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FIS	Flood Insurance Studies
FMD	Future Maintenance Dredge
FOS	factor of safety
fps	feet per second
FS	Feasibility Study
ft/s ²	foot per second squared
HC&C	hydraulic control and containment
HEA	Habitat Equivalency Analysis
ITRC	Interstate Technology Regulatory Council
KI	Koppers Industries
lb/ft ³	pound per cubic foot
LWG	Lower Willamette Group
MGP	manufactured gas plant
NAPL	nonaqueous phase liquid
NAVD88	North American Vertical Datum of 1988
NCDC	National Climactic Data Center
NMFS	National Marine Fisheries Service
NN	Natural Neighbor
NOAA	National Oceanic and Atmospheric Administration

NPDES	National Pollutant Discharge Elimination System
NRC	not reliably contained
OAR	Oregon Administrative Rule
OHSRA	Oregon Hazardous Substance Remedial Action
OHW	ordinary high water
OLW	ordinary low water
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PHNRTC	Portland Harbor Natural Resources Trustees Council
Portland Harbor Site	Portland Harbor Superfund Site
psf	pound per square foot
PTW	principal threat waste
RAL	remedial action level
RAO	remedial action objective
RBC	risk-based concentration
RHV	relative habitat value
RI	Remedial Investigation
RNA	Restricted Navigational Area
ROD	Record of Decision
SEF	Sediment Evaluation Framework
Siltronic	Siltronic Corporation
SMA	sediment management area
SOW	Statement of Work
TBC	To Be Considered
TCLP	toxic characteristic leaching potential
USACE	U.S. Army Corps of Engineers
WBZ	Water Bearing Zone
Work Plan	<i>Pre-Remedial Basis of Design Technical Evaluations Work Plan</i>
WQMP	Water Quality Monitoring Plan

1 Introduction and Objectives

This *Pre-Remedial Basis of Design Technical Evaluations Work Plan* (Work Plan) has been prepared by Anchor QEA, LLC, on behalf of NW Natural for the Gasco Sediments Site, located on the Willamette River adjacent to the NW Natural “Gasco” and Siltronic Corporation (Siltronic) properties in Portland, Oregon (Figure 1). This Work Plan has been prepared under the Administrative Settlement Agreement and Order on Consent (AOC; Docket No. CERCLA 10-2009-0255) and attached Statement of Work (SOW; EPA 2009), and the Schedule of Deliverables approved by the U.S. Environmental Protection Agency (EPA) on June 19, 2017. This Work Plan presents the methodologies that will be used to update the Gasco Sediments Site active cleanup boundaries (herein termed the Project Area) and to perform technical evaluations consistent with the Portland Harbor Superfund Site (Portland Harbor Site) Record of Decision (ROD; EPA 2017a) to develop a remedial design for the Gasco Sediments Site.

1.1 Work Plan Purpose and Objectives

The purpose of this Work Plan is to define performance standards for design of the Gasco Sediments Site remedy. It includes a description of the proposed methodologies to define the boundaries of the Gasco Sediments Site Project Area, the proposed site-specific technical evaluation methodologies for remedial technology assignment, and pertinent pre-design work completed in the *Draft Engineering Evaluation/Cost Analysis* (Draft EE/CA; Anchor QEA 2012a). This information will allow NW Natural and EPA to reach a common understanding of the standards and methods by which information and analyses from the Draft EE/CA will be carried forward into post-ROD remedial design. It will also assist NW Natural and EPA in the identification of data needs prior to initiation of the specified technical evaluations and the remedial design process as a whole. Following EPA approval of this Work Plan, NW Natural will prepare a Data Gaps Sampling and Analysis Plan for the collection of data necessary to complete the technical evaluations, implement the sampling and analysis, and perform the EPA-approved technical evaluations following receipt of the validated data.

1.2 Document Organization

The remainder of this document is organized into the following sections:

- Section 2 – RAOs, ARARs, and Cleanup Levels
- Section 3 – Identification of Final Project Area
- Section 4 – Pre-Remedial Design Technical Evaluations
- Section 5 – Sediment Remedy Basis of Design Technical Evaluation Memoranda
- Section 6 – References

The following appendices are attached to this document:

- Appendix A – Habitat Equivalency Analysis Workbook Template
- Appendix B – Portland Harbor Natural Resource Trustee Council and NMFS Relative Habitat Values

2 RAOs, ARARs, and Cleanup Levels

2.1 Remedial Action Objectives

Remedial action objectives (RAOs) consist of media-specific goals for protecting human health and the environment. Page 8 of the Gasco Sediments Site SOW (EPA 2009) states, “Because the goal of this project is to design a final remedial alternative that can be included in the Portland Harbor Proposed Plan, the RAOs shall be consistent with the RAOs being used for the wider Portland Harbor site.” In the ROD (EPA 2017a), EPA developed nine RAOs for contaminants of concern (COCs) in the environmental media of interest; exposure pathways, including exposure routes and receptors; and an acceptable contaminant concentration or range of concentrations for each exposure route. These RAOs were developed to address the human health and ecological risks posed by sediment contamination at the Portland Harbor Site, including the Gasco Sediments Site. The nine ROD RAOs are directly quoted in italics as follows:

Human Health RAOs

- *RAO 1 – Sediment: Reduce cancer and non-cancer risks to people from incidental ingestion of and dermal contact with COCs in sediment and beaches to exposure levels that are acceptable for fishing, occupational, recreational, and ceremonial uses.*
- *RAO 2 – Biota: Reduce cancer and non-cancer risks to acceptable exposure levels (direct and indirect) for human consumption of COCs in fish and shellfish.*
- *RAO 3 – Surface Water: Reduce cancer and non-cancer risks to people from direct contact (ingestion, inhalation, and dermal contact) with COCs in surface water to exposure levels that are acceptable for fishing, occupational, recreational, and potential drinking water supply.*
- *RAO 4 – Groundwater: Reduce migration of COCs in groundwater to sediment and surface water such that levels are acceptable in sediment and surface water for human exposure.*

Ecological RAOs

- *RAO 5 – Sediment: Reduce risk to benthic organisms from ingestion of and direct contact with COCs in sediment to acceptable exposure levels.*
- *RAO 6 – Biota (Predators): Reduce risks to ecological receptors that consume COCs in prey to acceptable exposure levels.*
- *RAO 7 – Surface Water: Reduce risks to ecological receptors from ingestion of and direct contact with COCs in surface water to acceptable exposure levels.*

- *RAO 8 – Groundwater: Reduce migration of COCs in groundwater to sediment and surface water such that levels are acceptable in sediment and surface water for ecological exposure.*

Human Health and Ecological

- *RAO 9 – Riverbanks: Reduce migration of COCs in riverbanks to sediment and surface water such that levels are acceptable in sediment and surface water for human health and ecological exposures.*

2.2 Applicable or Relevant and Appropriate Requirements and To Be Considered

The design of a final remedy for the Gasco Sediments Site will include an assessment of the ability of the remedy to address Applicable or Relevant and Appropriate Requirements (ARARs) of environmental laws and other standards or guidance “To Be Considered” (TBC).

A summary of key ARARs that will be used to develop the design for the Gasco Sediments Site remedy are provided in Table 1. The list in Table 1 includes certain regulatory citations that may not be applicable or relevant to some portions of the Gasco Sediments Site design or to the Gasco Sediments Site itself, but may be applicable or relevant to other locations or aspects of the entire Portland Harbor Site sediment remedy. Some may be eliminated from further consideration in development of the Gasco Sediments Site design if they are not applicable or not relevant.

A detailed review of action and location-specific ARARs specific to the Gasco Sediments Site remedy will be conducted and included in Gasco Sediments Site remedial design documents. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), permits from other federal, state, or local regulatory authorities are not required for actions conducted within the CERCLA site. However, remedial actions must comply with substantive provisions of ARARs.

The methods by which substantive compliance with ARARs will be demonstrated are presented in other sections of this Work Plan, and the final documentation of substantive compliance with ARARs will be provided as part of the Gasco Sediments Site design documents.

2.3 Portland Harbor ROD Cleanup Levels

Cleanup levels are the long-term contaminant concentration targets to be achieved by the Portland Harbor Site sediment remedy to meet RAOs.

The ROD identified cleanup levels for the following media: sediment (including beaches), riverbank soil,¹ surface water, and groundwater. EPA also developed human health targets for fish/shellfish

¹ The ROD identified one set of cleanup levels for “riverbank soil/sediment.”

tissue through either risk-based or ARAR-based approaches. Section 9.1.1 of the ROD (page 56) states, "These levels of chemicals in fish/shellfish tissue are not cleanup levels but will be monitored throughout the cleanup and will, at a minimum, be used to inform fish advisories."

Table 2 presents the ROD-identified cleanup levels or targets for each of the affected media and whether the selected value is risk-based, ARARs-based, or based on background concentrations (if risk- or ARAR-based concentrations fell below background).

3 Identification of Final Project Area

The ROD (EPA 2017a) does not delineate the Gasco Sediments Site “work area” approved by EPA in the Gasco Sediment Site Draft EE/CA (or any other work area through the Portland Harbor Site; Anchor QEA 2012a); therefore, the Gasco Sediments Site Project Area established in the Draft EE/CA needs to be refined to be consistent with the ROD for remedial design. As described in Section 3.4.1.2 of the Gasco Sediments Site SOW (EPA 2009), the Project Area will be identified in an iterative fashion through the course of data gathering, alternatives evaluation, and design. Appendix A of the Draft EE/CA presented the refined Interim Project Area, based on lines of evidence and information from the *Gasco Sediments Cleanup Action Final Work Plan* (Anchor QEA 2010a), the *Final Project AIR and Data Gaps QAPP* (Project AIR; Anchor QEA 2010b), and results of the 2010 and 2011 Project AIR (Anchor QEA 2010b) data gaps sampling events (Figure 1).

This section describes the process that will be used to develop the Final Project Area based on refinement of the Draft EE/CA Interim Project Area using the sediment management area (SMA) lines of evidence delineation presented in the ROD and forthcoming site-specific data collection necessary to support the remedial design process. Specifically, the Final Project Area will be identified based, in part, on the following lines of evidence:

1. Presence of principal threat waste (PTW)
2. Exceedances of remedial action levels (RALs)
3. Additional considerations for the upriver, downriver, and channelward extents

Significant benthic toxicity data have been collected within the Interim Project Area and are summarized in the Draft EE/CA (Anchor QEA 2012a). As appropriate, these pre-construction data may be used to help evaluate long-term performance of the completed Gasco Sediments Site remedy.

3.1 Presence of Principal Threat Waste

Section 6.5.1 of the ROD (page 20) states, “Principle threat waste (PTW) is defined as source material that includes or contains hazardous substances, pollutants, or contaminants that act as a reservoir for the migration of contamination to groundwater, surface water, or air or that acts as a source for direct exposure. Further, principle threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur.”

The ROD identified the following three forms of PTW:

- **PTW-NAPL:** PTW-NAPL was identified in the ROD as nonaqueous phase liquid (NAPL). The lateral extents of PTW-NAPL (Figure 2) identified in the ROD will be directly adopted for development of the Final Project Area. Any future surface and subsurface sediment or top of

riverbank soil samples (see Section 4.3.6) collected within the Gasco Sediments Site will be visually evaluated for the presence of NAPL consistent with the ROD definitions, and the lateral and vertical extents of PTW-NAPL in the Final Project Area will be refined, as necessary.

- **PTW-Highly Toxic:** The ROD identified PTW-highly toxic concentrations are summarized in Table 3. The ROD-identified lateral extents are depicted in Figure 2 and will be directly adopted for development of the Final Project Area, excluding the area associated with sediment core station C300-2 in the channel that is associated with elevated polychlorinated biphenyl (PCB) concentrations. Any future surface sediment samples collected within the Gasco Sediments Site will be compared against the PTW-highly toxic concentrations in Table 3, and the lateral extents will be revised, if necessary.
- **PTW-NRC:** For the purposes of the EPA *Portland Harbor RI/FS Feasibility Study* (EPA FS; EPA 2016) and ROD (2017a), EPA developed an FS-level cap model to identify PTW that are not reliably contained (NRC) by a cap. The ROD states, "This is an appropriate model to make FS-level decisions and is sufficiently rigorous to be used for decision-making at the FS phase. More rigorous modeling may be conducted as needed in remedial design" (EPA 2017a; page I-163). The FS-level cap model assumed site-wide conditions and input parameters to determine an assumed maximum concentration of COCs in PTW material that would not exceed ambient water quality criteria in the sediment cap porewater after a period of 100 years. Chlorobenzene, dioxins/furans, DDx, naphthalene, polycyclic aromatic hydrocarbons (PAHs), and PCBs were modeled. The FS-level modeled PTW-NRC concentrations are summarized in Table 4, and the lateral extents are depicted in Figure 2. The lateral extents of PTW-NRC identified in the ROD will be refined using a design-level cap model that incorporates Gasco Sediments Site-specific input parameters, including measured groundwater seepage fluxes during operation of the hydraulic control and containment (HC&C) system in the Gasco property uplands and porewater concentrations.

The footprints of all three forms of PTW will be mapped in the in-water sediments areas, and the Final Project Area will encompass the outer boundary of each form. As discussed in Section 3.4, the three forms of PTW are not used for evaluation of the Final Project Area in the riverbank.

3.2 Portland Harbor ROD Remedial Action Levels

The Portland Harbor ROD establishes sediment RALs that are used to define areas of sediment requiring active remediation to achieve the ROD-identified cleanup levels. RALs were developed for select contaminants of interest that bound areas that may also be impacted by other contaminants. Therefore, sediment remediation of areas established based on the select contaminants of interest will also address the remaining contaminants potentially posing unacceptable risk, as described in the ROD. Table 5 summarizes the ROD-identified RALs that apply to areas within and outside the navigation channel, respectively. These RALs will be directly applied at the Gasco Sediments Site.

EPA's contouring and mapping procedures create some mapping artifacts due to the assumption of splitting the contouring procedure at the navigation channel line (e.g., long thin extensions of the SMAs along the navigation channel change boundaries where no sampling points exist).² The RAL delineation for the Gasco Sediments Site remedial design will interpolate RAL exceedances using the Natural Neighbor (NN) algorithm (the same algorithm used by EPA in the EPA FS and ROD). To refine the NN contouring for the appropriate design-level spatial scale, NW Natural proposes to interpolate the samples from the east and west sides of Portland Harbor independently; each side will be combined with the samples taken in the navigation channel to avoid results on the opposing side influencing interpolation, while the navigation channel will be interpolated by itself. This refinement will minimize the long thin delineation artifacts along the channel lines, particularly where no data exist within these long thin areas to support such contouring.

3.3 Refinement of SMAs Based on Additional Data Collection

Following release of the ROD (EPA 2017a), EPA released the *Portland Harbor Superfund Site – Sampling Plan for Pre-Remedial Design, Baseline, and Long-Term Monitoring, Revised Working Draft* (EPA 2017b). This document describes the approach for performing preliminary remedial design characterization for further delineation of the SMAs identified in the ROD. The document states:

“Sediment cores will be advanced within the SMA footprints and spaced on a 150-by 150-foot grid. This grid spacing was selected to be consistent with the SMA characterization performed by the RM11E group. Additionally, a 150-foot buffer zone of sediment core “step out” locations will be advanced to delineate the extent of COCs above the applicable RAL and PTW thresholds. If COCs are above the applicable RAL and PTW thresholds at a step out location, then an additional core will be advanced no farther than 150 feet from the core location(s) with COCs above the RAL and PTW thresholds. This process will continue until the lateral extent of sediment above the applicable RAL and PTW thresholds is delineated and the vertical extent of COCs above the applicable RAL and PTW thresholds is delineated to the depth of feasible dredge limits or to characterize material to be capped consistent with the Selected Remedy... Specific details regarding the sampling program (e.g., sample location, depth, step out core installation procedures, archiving procedures) shall be presented in project plans and subject to EPA approval.”

Due to the extensive pre-design level of sampling performed by NW Natural for the Draft EE/CA (Anchor QEA 2012a) pursuant to the 2009 AOC, a significant amount of data is already available and has been previously reported for the Gasco Sediments Site. NW Natural will evaluate the core density both within and surrounding the ROD-identified SMA boundaries to determine if additional

² Appendix N of the EPA FS (EPA 2016) details a variety of uncertainties behind any contouring procedure and supports refinement of RAL delineation in specific work areas during design.

characterization is necessary to refine the boundaries. The results of this evaluation will be presented in the Pre-Remedial Design Data Gaps Work Plan and Sampling and Analysis Plan to be submitted to EPA following EPA approval of this Work Plan.

3.4 Riverbank

Section 14.2.9.5 of the ROD (page 116) states, "In an SMA, contaminated river banks will be remediated through this cleanup where they are contiguous with in-river contamination or where they pose a risk of recontamination to the Selected Remedy." Section 3.4.1.3 of the Gasco Sediments Site SOW (EPA 2009; page 17) states the following:

"The riverbank is included in the project area to facilitate consistencies between riverbank remediation, source control work and the in-river sediment cleanup. The need for riverbank work shall be determined by:

1. *the need for soils remediation consistent with the upland Gasco property risk assessment and FS*
2. *the need to control sources of contaminants from the riverbank to the river including*
 - a. *processes of soil erosion,*
 - b. *leaching of chemicals due to shallow groundwater movement through the bank,*
 - c. *and/or stormwater infiltration and discharge through riverbank soils."*

Consistent with these statements, the Final Project Area will encompass the entire riverbank (from the toe to the top of slope) adjacent to all identified sediment areas subject to remediation within the Final Project Area. See Section 4.4 for more details on the riverbank remedy evaluation within the Final Project Area.

3.5 Additional Considerations for Final Project Area Extents

The upriver, downriver, and channelward extents of the Final Project Area will also be developed using the following additional secondary lines of evidence:

- Presence and absence of PAH chemical concentrations and concentration gradients
- Presence of non-PAH chemical concentrations
- Physical features, such as dock structures
- Property ownership and operations

This is consistent with the ROD (page 116): "While such decisions have not yet been made, EPA may manage the Portland Harbor cleanup by dividing the Site into smaller work areas for purposes of design and construction activities based on factors such as prioritization of significant source areas, logistics, efficiency, or other factors." That is, the ROD recognizes that work areas need to be refined to encompass discreet areas to support efficient design and construction of remediation.

In addition to the physical lines of evidence listed above, practical aspects of efficient project management will also be evaluated when developing the Final Project Area. All lines of evidence will be compiled, and the resulting Final Project Area will be presented to EPA in the form of a technical briefing. This briefing will provide the rationale for the downriver, channelward, and upriver extents of the Final Project Area and will subsequently be memorialized in a submittal to EPA.

3.6 Project Area Characterization

Following EPA approval of the Final Project Area, the following site characteristics within the Final Project Area will be presented to serve as the basis for the Basis of Design Technical Evaluation Memoranda:

- Site topography and bathymetry
- In-water structures
- Upland source control structures
- Geotechnical conditions
- River conditions (typical flows, flood flows, and flood frequencies)
- Wave conditions (both wind-generated and wake-generated)
- Propeller wash conditions (e.g., vessels that call on the Gasco Sediments Site)
- Elutriate data

The upland and in-water structures that may be impacted by the sediment remedy will also be considered in the Basis of Design Technical Evaluation Memoranda. A summary of these structures is provided below to provide context for the evaluations described in Section 4.

3.6.1 *Gasco Property*

The primary in-water structure within the Final Project Area is the NW Natural Gasco fuel pipeline dock (Figure 3). The dock has existed in the central shoreline area since 1936 and is actively used by PacTerm for import and export of products related to its operations. Vessels that access the dock use the two shoreline dolphins and pedestrian piers. The channelward dock face is accessed via north and south access ramps that extend from the top of riverbank over the river. Outfall 107 is located upriver of the dock south access ramp and is the major stormwater discharge point for the property. One other small active stormwater outfall (WR-467) discharges from the riverbank just north of the north dock access ramp. Outfall 001 serves the upland source control water treatment system and is also attached to and discharges underwater from a dock support structure near the middle of the dock. The PacTerm Lease Area has several structures near the shoreline, including secondary containment basins and aboveground storage tanks, the office building, and underground utilities. Lastly, an emergency slide for deploying and retrieving spill containment booms is located on the riverbank just downriver from the dock north access ramp.

3.6.2 *Siltronic Property*

Three outfalls are located along the Siltronic shoreline: a single submerged outfall (WR-66) near the Gasco-Siltronic property line extends and discharges treated wastewater from Siltronic processes and stormwater through a diffuser into the river, and two stormwater outfalls (WR-67 and WR-287) discharge from the riverbank further south (Figure 4). The submerged outfall structure is supported in place by pilings.

Directly adjacent to the Siltronic top of bank is the Fab 1 building and associated access road. Fab 1 operations include continuous silicon wafer manufacturing and quality assurance support for the Fab 2 operations. Siltronic has reported that these operations are extremely sensitive to vibrations and that significant vibration-creating construction may result in product damage, facility shut down, and lost revenue. Wafer manufacturing operations at Fab 1 are not occurring at present, and utilization of Fab 1 for manufacturing or other operational support by Siltronic may vary from past or current uses in the future. The Fab 1 access road along the top of bank provides access for manufacturing and emergency equipment and requires unlimited access. Operation-critical utilities, including a 15-kilovolt electrical supply line, fire suppression support, and stormwater drainage, are located under and adjacent to the Fab 1 access road.

3.6.3 *Upland Source Controls*

The sediment and riverbank remedy design will consider impacts to the existing upland HC&C source control system infrastructure currently present at the Gasco and Siltronic properties, as well as future Fill Water Bearing Zone (WBZ) controls evaluated as part of the Gasco upland feasibility study. This source control work is being completed consistent with the requirements of the Joint Order between the Oregon Department of Environmental Quality (DEQ), NW Natural, and Siltronic (DEQ Order No. ECVC-NWR-00-27, dated October 4, 2000), with the requirements of the Voluntary Agreement between DEQ and NW Natural (DEQ Order No. WMCVC-NW-94-13, dated August 8, 1994, as amended July 19, 2006, and October 11, 2016), and in coordination with EPA. The existing system is designed to prevent the discharge of contaminated groundwater from the Alluvial WBZ to the river in perpetuity (i.e., the sediment remedy design will assume this system is operational for the entire sediment remedy performance period). The HC&C system was substantially completed in 2013 and was approved for long-term operation in December 2016 (DEQ 2016). The system consists of two major components: the groundwater HC&C system and the groundwater treatment system. The locations of the major components of the system are shown in Figures 3 and 4. These components include 25 extraction wells and associated underground piping adjacent to the top of riverbank. The Siltronic pretreatment plant, the NW Natural pretreatment plant, and the main treatment plant are further removed from the riverbank. Groundwater from the extraction wells is treated and the effluent is pumped and discharged to the river via the groundwater treatment outfall (Outfall 001; Figure 3).

4 Pre-Remedial Design Technical Evaluations

This section describes the proposed pre-design technical evaluation methodologies to design the EPA-selected remedy defined in the ROD (EPA 2017a) for the Gasco Sediments Site. Methodologies are proposed for the following technical evaluations:

1. Gasco Sediments Site Use Evaluation
2. Capping Demonstration
3. Riverbank Remedy
4. Dredging
5. Dredge Sediment Waste Handling and Transport
6. Waste Disposal Determination
7. Functional Structures
8. Water Quality Best Management Practices
9. Habitat Modification
10. Flooding Impact

For each technical evaluation, NW Natural has identified the data requirements and whether any data gaps exist to complete the evaluation. For those technical evaluations where data gaps exist, the specific data quality objectives, sampling methodologies, and physical and chemical analyses will be identified in the Pre-Remedial Design Data Gaps Work Plan and Sampling and Analysis Plan to be submitted to EPA following EPA approval of this Work Plan. NW Natural also provides a summary of the operational considerations to support the design process and information that will be included in the various Pre-Remedial Design Basis of Design Technical Evaluation Memoranda for each technical evaluation following completion of the pre-remedial design data gaps sampling.

4.1 Gasco Sediments Site Use Evaluation

The Gasco Sediments Site remedy will need to account for ongoing and future site uses at the Gasco and Siltronic properties and surrounding site uses. Evaluations will be performed for the following site use areas within the Final Project Area: the Willamette River navigation channel (navigation channel), the future maintenance dredge (FMD) area located between the navigation channel and the existing Gasco fuel pipeline dock, the USACE U.S. Moorings dock, and Siltronic outfalls.

Navigation Channel and FMD Area. A substantial portion of the Interim Project Area is within the federally authorized and maintained navigational channel. In 1999, Congress authorized the Willamette River (and Columbia River) deepening to -37.8 feet North American Vertical Datum of 1988 (NAVD88; -43 feet Columbia River Datum [CRD]), but to date, the USACE has not conducted any additional maintenance dredging to achieve this depth in the Willamette River channel. The channel is navigated by a variety of small and large vessels moving in and out of Portland Harbor. Evaluations will be performed to understand how the Gasco Sediments Site remedy can or cannot

impact the ongoing navigation uses. The FMD area is located between the federal navigation channel and the existing Gasco dock (described below). The elevation within the FMD is maintained to a depth of -34.8 feet NAVD88 (-40 feet CRD).

Gasco Fuel Pipeline Dock. The fuel pipeline dock was previously used for pencil pitch transfer via large oceangoing vessels and is currently used for petroleum product transfers via barges. Two mooring dolphins exist upstream and downstream of the dock along the shoreline, which are used to secure vessels when docked. There is also a small floating dock just downstream of the primary dock that is used to moor smaller boats that support product transfer and other operations (Figure 3). An evaluation will be performed to determine potential impacts to remedial technology assignments given current and potential future site uses involving the Gasco dock. The Gasco dock is actively in use and is a registered structure on land owned by the Oregon Department of State Lands (DSL) through June 2024 (DSL 2014). Per the ROD, capping is the preferred technology assignment within the footprint of permanent structures. The design will also evaluate additional structural considerations such as dredging offsets needed to preserve structural integrity and preservation of normal access means and corridors. In addition to the site use evaluations related to the Gasco fuel pipeline dock, a functional structure evaluation will be performed on the Gasco dock as described in Section 4.7.

U.S. Moorings Dock and FMD Area. The USACE U.S. Moorings Dock is located on the downstream boundary of the Interim Project Area (Figure 2). NW Natural understands that the elevation of the FMD area located on the channelward side of the dock is generally maintained to -24.8 feet NAVD88 (-30 feet CRD) and that no vessel moorage occurs on the upriver side of the dock within the Interim Project Area. An evaluation will be performed to understand and minimize the potential impacts to the use of the dock and avoid increases to the pre-construction mudline elevations in the FMD area during completion of the Gasco Sediments Site remedy

Siltronic Outfalls. As described in Section 3.6.2, three outfalls located along the Siltronic shoreline discharge stormwater and process water to the Willamette River (Figure 4). In addition to the site use evaluations, a functional structure evaluation will be performed on the Siltronic outfall systems as described in Section 4.7.

No data gaps are identified to support completion of the Gasco Sediments Site use evaluations.

4.2 Capping Demonstration Evaluation

As discussed in NW Natural's planning meetings with EPA, the capping demonstration evaluation for the Final Project Area will be based on the performance standards and design objectives, site-specific evaluation of 10 physical and chemical capping elements, and evaluation of operational considerations presented in the following subsections. This evaluation applies to both in-water

sediments and riverbank sediments. A summary of the data requirements and currently identified data gaps associated with this evaluation and a summary of the information that will be included in the Basis of Design Technical Evaluation Memorandum for this evaluation is also presented.

4.2.1 Performance Standards and Design Objectives

Capping performance standards are discussed within each capping design element.

The following cap design objectives will be used in the remedial design process:

- Design a cap that isolates contaminants from human health and ecological risks.
- Design a cap that can withstand erosive forces from currents, wind-induced waves, vessel-induced waves, and vessel propeller wash.
- Design and place a cap in a way that will not exceed the bearing capacity and shear strength of the underlying sediments.
- Conduct the work consistent with a Water Quality Monitoring Plan (WQMP) to minimize water quality impacts outside the compliance boundary.
- Conduct the work consistent with a Biological Opinion developed by National Oceanic and Atmospheric Administration (NOAA) Fisheries.

4.2.2 Design Elements Necessary for Capping Demonstration

USACE (Palermo et al. 1998a) and EPA (Palermo et al. 1998b) have both developed cap design guidance documents that are recognized as the national standards. Figure 5 is a flow chart developed by EPA (Palermo et al. 1998b) that illustrates the five steps involved in the design evaluation of various cap components. These guidance documents categorize the cap design into the following components:

- Physical Isolation Component
 - Direct contact—determine the required cap necessary to reduce potential exposure due to direct contact and reduce the ability of burrowing organisms to move contaminants to the surface.
- Stabilization/Erosion Protection Component
 - Stabilization—determine the grain size required to prevent movement of underlying solids upwards through the cap.
 - Erosion—determine the grain size and thickness required to prevent erosion of the cap. Erosive forces to be considered include hydrodynamic, wind-induced waves, vessel-induced waves, and vessel propeller wash.
- Chemical Isolation Component
 - Contaminant transport—determine the cap characteristics necessary to control the fate and transport of chemicals (both dissolved and sorbed phase) under the processes of advection, diffusion/dispersion, biodegradation, bioturbation/bioirrigation, and

exchange of porewater from surface sediments with the overlying surface water to acceptable levels. If acceptable levels are not feasible, the use of treatment layers within the cap will be assessed for acceptability.

- Geotechnical Component—once the required thickness and extent of the cap is determined, a number of geotechnical considerations need to be assessed:
 - Bearing capacity—assess if the sediments underlying the cap have enough shear strength to support the cap.
 - Slope stability—if the cap is to be constructed on a slope, assess if the sediment underlying the cap, as well as the cap itself, have sufficient shear strength to remain stable during static and dynamic loading.
- Operational Component—practices and controls that may need to be implemented to ensure that the cap functions as designed and remains intact for the design life. These considerations may include planned maintenance of the cap, restrictions on uses of the waterway at the cap area, and other institutional controls.

In addition, EPA (2005) and the Interstate Technology Regulatory Council (ITRC; 2014) have developed guidance for the remediation of contaminated sediments. These guidance documents provide a remedy selection framework to help identify technologies favorable to site conditions and describe factors that should be considered as part of a site-specific capping evaluation.

The draft EPA remedial technology decision trees for the Portland Harbor Site dated October 30, 2015, identified 10 technical elements that need to be evaluated to demonstrate cap suitability for any given area. While these specific demonstration elements were not explicitly referenced in the Proposed Plan or ROD, they continue to represent a reasonable framework with which to define where capping is potentially appropriate and consistent with the intent of the flexible ROD technology application decision tree. While the ROD uses decision trees to assign dredging and capping to certain areas, the ROD also recognizes on pages 71 and 106 that “further modifications may be necessary during design to ensure the final constructed remedy is appropriate for the actual Site conditions.”³ As a result, the appropriateness and effectiveness of capping for any given area will need to be further defined in design based on site-specific data, and EPA’s 10 technical elements provide a sound basis for such a determination. EPA’s 10 technical elements are as follows:

- Element 1—Containable (i.e., Contaminant Confinement): demonstrate the contamination can reliably be physically and chemically contained
- Element 2—Flood Rise (i.e., Flood Flow Impacts): demonstrate the cap can be placed without causing unacceptable flood rise

³ The Responsiveness Summary also states, on page 2-143, that “EPA agrees that maintaining flexibility in type of construction methods through the remedial design phase is an important consideration” and refers to the decision tree as “flexible.”

- Element 3—Erosion Resistance: demonstrate the cap will remain in place when subjected to flow, wave, and anthropogenic-induced erosive forces
- Element 4—Presence and Effect of Debris: demonstrate debris will not prevent an effective cap from being designed and implemented⁴
- Element 5—Slope Stability: demonstrate the slope can support the cap
- Element 6—Sediment Bed Characteristics (i.e., bearing capacity): demonstrate the sediment bed can adequately support the cap
- Element 7—Treatment Requirements: demonstrate the cap treats EPA-defined PTW to the extent practicable
- Element 8—Shallow (i.e., habitat impacts): demonstrate placement of the cap will not result in unacceptable loss of shallow water habitat
- Element 9—Habitat (i.e., habitat mitigation, as necessary): demonstrate adverse effects on natural resources will be avoided or mitigated
- Element 10—DSL Cap Authorization Requirements: demonstrate DSL approves of cap placement in the proposed location

Elements 1, 3, and 6 of the EPA-identified ten technical elements are directly captured by the *Guidance for Subaqueous Dredged Material Capping* (Palermo et al. 1998a) and *Guidance for In-Situ Subaqueous Capping of Contaminated Sediments* (Palermo et al. 1998b) cap design guidance flowchart (Figure 5) or generally addressed in *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA 2005) and *Contaminated Sediments Remediation: Remedy Selection for Contaminated Sediments* (ITRC 2014). Elements 2, 4, 5, and 7 through 10 are specific to the Portland Harbor Site and addressed in the EPA FS (EPA 2016). Each of the ten capping demonstration elements is further discussed in the following subsections and draws upon capping guidance documents for specific, accepted methods of analysis, where relevant.

4.2.3 *Element 1—Contaminant Confinement*

Physical isolation and chemical isolation are the two main components to demonstrate that the contaminated sediment can be readily contained (Palermo et al. 1998a, 1998b; EPA 2005; ITRC 2014). The methods for demonstrating the performance of physical isolation and chemical isolation are each described below.

4.2.3.1 **Physical Isolation**

Two potential contaminant pathways exist via direct physical contact with contaminated sediment—bioaccumulation and bioturbation (EPA 2005; ITRC 2014). Physical isolation is required if a

⁴ Although EPA's purpose for this demonstration is not fully described, the Gasco Sediment Site capping demonstration method clarifies that the presence of debris will not prevent an effective cap from being designed and implemented. This determination may depend on both the characteristics of the debris or the ability to remove the debris to allow for an effective cap design.

site-specific evaluation shows an existing contaminant transport pathway from direct benthos-sediment contact or from bioaccumulation in benthos-consuming species. Additionally, benthic organisms can enhance contaminant transport through bioturbation or burrowing into sediments. To prevent direct physical contact and contaminant migration, a cap needs to be designed to physically isolate contaminated sediment from benthic (and other) organisms (Palermo et al. 1998a, 1998b; EPA 2005; ITRC 2014).

The proposed performance standard for physical isolation is as follows:

- Demonstrate the cap will be thick enough or coarse-grained enough to prevent direct contact by benthic organisms with the underlying contaminated sediments.

4.2.3.1.1 Method of Analysis

ITRC (2014) states, "Note that a cap need not be thicker than the depth of all organism activity. Some organisms may penetrate deeply, but most organisms and significant mixing activity is limited to 5 – 15 cm, or even less in some environments. The primary concern is the depth of sustained, significant bioturbation activity and not occasional deeper penetrations." Consistent with this guidance, the physical isolation layer requirements will be determined by evaluating the depth of sustained, significant bioturbation habits of benthos known or anticipated to reside in and around the cap area following construction completion (Clarke et al. 2001). This determination will take into account the physical characteristics of the cap and armor material and benthos that will repopulate a material with those characteristics. For example, medium- to fine-grained sand caps will likely be repopulated by midges and worms, whereas sand caps with stone-sized gravel armoring will attract additional species that attach to surfaces or inhabit interstitial spaces. The determination will also consider changes to the cap physical characteristics over time due to the natural long-term deposition of sediments over the cap that will fill or bury the interstitial spaces of the cap material.

Contact of benthic organisms with the underlying contaminants is prevented, and the sediment is physically isolated if the depth of expected future sustained significant bioturbation, given the proposed cap grain sizes, is less than the proposed cap design thickness.

4.2.3.1.2 Data Requirements and Data Gaps

Consistent with guidance (Clarke et al. 2001), literature information on bioturbation depths of freshwater benthos known to reside in the Lower Willamette River will be used to determine the expected bioturbation depths (and other bioturbation characteristics) compatible with the proposed physical characteristics of the cap and accounting for any long-term deposition of sediment overtop the cap surface. Per data collected from surveys of benthic invertebrates in the Lower Willamette River in October 2002 and July 2005, EPA (2015) estimated that the burrowing depths of these organisms is approximately 4 to 10 centimeters (1.5 to 4 inches).

This existing Portland Harbor Site-specific information is sufficient for use in design, so no data gaps are identified.

4.2.3.2 Chemical Isolation

As described in Palermo et al. (1998b):

"If a cap has a properly designed physical isolation component, contaminant migration associated with the movement of sediment particles should be controlled. However, the vertical movement of dissolved contaminants by advection (flow of ground water or pore water) through the cap is possible, while some movement of contaminants by molecular diffusion (movement across a concentration gradient) over long periods usually is inevitable. However, in assessing these processes, it is important to also assess the sorptive capacity of the cap material, which will act to retard contaminant flux through the cap, and the long-term fate of capped contaminants that may transform through time. Slow releases of dissolved contaminants through a cap at low levels will generally not create unacceptable exposures. If reduction of contaminant flux is necessary to meet remedial action objectives, however, a more involved analysis to include capping effectiveness testing and modeling should be conducted as a part of cap design."

Consistent with this guidance, the purpose of a chemical isolation component is to contain the release of chemicals through advective and diffusive flux processes from the contaminated sediments upwards through the cap. A short-term form of dissolved phase contaminant advection occurs when a cap material consolidates, temporarily causing the porewater to advect upward through the cap. This process stops once the cap finishes consolidation. Long-term advection occurs if groundwater flow creates an upward hydraulic gradient through the cap material.

As presented in the Draft EE/CA (Anchor QEA 2012a) and the groundwater source control presentation to EPA by NW Natural on September 21, 2015 (Anchor QEA 2015), the upland Alluvial WBZ HC&C system reverses the offshore alluvium groundwater gradient (i.e., from toward the river to toward the upland) over a substantial portion of the Interim Project Area and, therefore, minimizes long-term contaminant advection to the river over most of the site, leaving only the diffusion process as a possible means of contaminant transport to the river. Long-term diffusive flux is addressed through appropriate design of the sorptive capacity of the cap material (Palermo et al. 1998b). The Alluvial WBZ HC&C system was in full-scale operation and testing mode from September 2013 to December 2016, when DEQ approved the system for long-term operation. The Fill WBZ groundwater containment technology will be in place before the sediment remedy is implemented. As discussed in Section 4.3.2.2, empirical data will be used to verify the effects of the operating Alluvial WBZ HC&C system on groundwater movement through sediment and further

validate the upland site MODFLOW groundwater model flow estimates. Given that the Fill WBZ system has not been constructed yet, nearshore Fill WBZ empirical groundwater flow measurements will be collected and used in conjunction with the validated MODFLOW estimates as a conservative measure of nearshore cap performance in Fill WBZ discharge zones. This approach is discussed more below.

The proposed performance standards for chemical isolation in areas with and without long-term advection are, therefore, as follows:

- Demonstrate that the long-term predicted average sediment concentrations in the top 10 cm (EPA's 2015 reported maximum burrowing depth of benthic organisms) of the material overlying the cap isolation layer (i.e., filter material in nearshore caps and sand material in offshore caps) will be less than ROD-identified RALs (e.g., related to sediment-dwelling organism exposures) (Table 5).
- Demonstrate that the long-term predicted surface water concentrations above the cap isolation layer and associated with groundwater flux through the cap are less than applicable ecological chronic surface water criteria (e.g., related to surface water-dwelling organism exposures). The conservative approach analysis compares pre-dilution porewater concentrations at a depth of 1 cm below the surface of the top of the modeled cap to the water quality criteria.

4.2.3.2.1 Method of Analysis

Consistent with EPA's cap modeling evaluations for the ROD, the chemical isolation modeling will be performed using sediment cap models developed by Dr. Danny Reible (Texas Tech University).⁵ These models have been used to support the design of sediment caps at numerous sites around the United States (ITRC 2014). The models are one-dimensional (i.e., vertical direction within a cap) and simulate the fate and transport of chemicals (both dissolved and sorbed phase) under the processes of advection, diffusion/dispersion, biodegradation, bioturbation/bioirrigation, and exchange of porewater from surface sediments with the overlying surface water. Figure 6 illustrates the different theoretical processes of contaminant transport through a cap. The time-variable Reible model will be used; the theory and solution techniques associated with the time-variable model are documented in Go et al. (2009). Documentation of published model inputs and outputs is also available on Dr. Reible's website (Reible 2012).

The model predicts chemical concentrations at the locations identified in the performance standards summarized above. Consistent with evaluations at other sites (including within the Portland Harbor Site at the Gasco 2005 Tar Body Early Action Removal Action and the Port of Portland Terminal 4

⁵ Predecessors to the Reible cap models are described in Appendix B of the EPA capping guidance document (Palermo et al. 1998b). This document serves as an informative general description of the underlying theory and equations used in the Reible models, but it must be noted that significant advancements have been made in the field of sediment cap design modeling since its publication.

designs), the model will be run through a time period appropriate for determination of the long-term effectiveness of the cap (e.g., 100 years), relevant to the expected design life of the cap. If the model-predicted concentrations exceed the water and sediment quality-based performance standards noted above, additional modeling will be performed to determine if the addition of treatment layers (such as activated carbon or organoclay) into the cap material will attain the performance standards.

4.2.3.2.2 Data Requirements and Data Gaps

The input parameters used in the cap modeling assessment are listed in Table 6, along with the proposed sources. The parameters were developed based on site-specific data, literature, and experience from other cap design projects. In selecting values, the values used in the cap effectiveness analysis documented in the EPA FS (EPA 2016) were considered. In many cases the values are identical to or very close to those used in the EPA FS. In other cases, small differences exist due to the use of different literature sources or updated site-specific information. One specific consideration for cap modeling at the Gasco Sediments Site is use of consistent sources/approaches for all chemicals simulated. Given that this design evaluation considers some chemicals that were not included in the EPA FS evaluation (i.e., benzene, TCE, DCE, and vinyl chloride), it was necessary to use different literature sources in some cases. Nonetheless, the values proposed herein are generally consistent with those presented in the EPA FS. Two key site-specific model input parameters are porewater concentrations underlying the cap and groundwater Darcy flux. Input values for these two parameters will be based on site-specific data from the Final Project Area, including data to be collected as part of pre-design investigations.

The capping evaluation developed in the Draft EE/CA (Anchor QEA 2012a) used porewater concentrations and groundwater Darcy velocities in the Interim Project Area prior to operation of the HC&C system. Groundwater Darcy fluxes were evaluated using a preliminary site-specific MODFLOW groundwater model developed in coordination with DEQ and EPA. Since that time, NW Natural has collected extensive groundwater data to calibrate the MODFLOW model and produce refined model estimates of offshore groundwater Darcy flux throughout the Final Project Area. NW Natural will evaluate chemical isolation using collected empirical offshore groundwater measurements, which will also support further refinement and validation of the MODFLOW groundwater model, as discussed in more detail below.

An EPA letter to NW Natural dated April 4, 2017, states, "EPA considers the primary lines of evidence to demonstrate off-shore seepage control to be empirical data to corroborate the groundwater model results and give confidence to model predictions. Such empirical lines of evidence should include measurement of vertical upwelling at the sediment-water interface in proposed capping areas using seepage meters and/or piezometers" (EPA 2017c). NW Natural agrees that additional collected empirical groundwater flow data collection will provide the primary line of evidence

supporting refinement of the cap modeling. Given that empirical groundwater flow measurements cannot be conducted for long periods or over all possible cap areas of the site, the empirical groundwater flow data will be used to further validate and refine the MODFLOW groundwater model, which may be used to augment empirical data in some areas and for some cap evaluations. As noted above, because a Fill WBZ system has not been constructed yet, nearshore Fill WBZ empirical groundwater flow measurements will be collected and used in conjunction with the validated MODFLOW groundwater model estimates as a conservative measure for nearshore cap performance in Fill WBZ discharge zones.

Cap model input values for water quality will use existing sediment and dissolved phase data supplemented by groundwater sample concentration data from nearby wells, if necessary. This data will be reviewed to identify if there are data gaps, and any identified data gaps will be filled as part of the Pre-Remedial Design Data Gaps Work Plan and Sampling and Analysis Plan to be submitted to EPA following EPA approval of this Work Plan.

4.2.4 *Element 2—Flood Flow Impacts*

Flood flow impacts from cap placement and other remedial technologies are discussed in Section 4.10.

4.2.5 *Element 3—Erosion Resistance*

As described in Palermo et al. (1998b):

“The cap component for stabilization/erosion protection has a dual function. On the one hand, this component of the cap is intended to stabilize the contaminated sediments being capped, and prevent them from being resuspended and transported offsite. The other function of this component is to make the cap itself resistant to erosion. These functions may be accomplished by a single component, or may require two separate components in an in-situ cap.”

A detailed assessment of cap erosion protection (i.e., armor layer) design is provided in Appendix A of Palermo et al. (1998b). For a cap to resist erosive forces, the armor materials must be designed to withstand flood-induced erosive forces, wind-induced waves, vessel-induced waves, and vessel propeller wash. The cap armor material gradation and thickness must also be designed to stabilize and protect the underlying physical and/or chemical isolation layers from the most severe case of erosion (based on an evaluation of each potential source).

The armor layer of the cap must also be designed to provide stabilization of underlying sediment and/or cap materials by preventing the vertical migration of cap materials (termed piping; Palermo et al. 1998b). In some cases, the armor layer gradation may be altered, or a separate filter

layer with a well-sorted gradation is added between the armor and physical or chemical isolation layers to prevent piping.

The proposed performance standards related to stabilization/erosion protection are as follows:

- Demonstrate that the cap armor layer material gradation will remain stable during the following erosive events:
 - River currents during flow conditions, up to the 100-year return interval flows
 - 100-year wind-generated waves
 - Vessel-generated waves from the site-specific design vessel and excursion vessels (i.e., jetboats)
 - Expected or likely propeller wash the site-specific design vessel
- Demonstrate that the cap gradation meets filter design requirements to prevent piping of underlying sediment and/or cap materials

4.2.5.1 Method of Analysis

Evaluation of river currents, wind-generated waves, vessel-generated waves, and propeller wash are required for the erosion protection component of the cap armor layer design (Palermo et al. 1998b). The methodology used to evaluate each potential source of erosion at the Final Project Area is described below. The largest required stable particle size (or larger) necessary to resist the different erosive forces will be selected as the minimum design armor material. Consequently, the resulting selected armor material will necessarily meet the first performance standard described above.

4.2.5.1.1 River Currents

To evaluate the potential effects of river currents during design flood conditions, a site-specific hydraulic or hydrodynamic model will be developed to simulate the conditions in the river (consistent with the flood flow model evaluations discussed in Section 4.10, although the exact same model may not be used for both purposes). The highest erosive event within the design life of a cap is not necessarily associated with the 100-year flood event. Once a river tops its bank, the flow energy can drop—therefore, the highest erosive event may correspond to a lower frequency flood event. Erosive forces up to the 100-year flood will be evaluated.

The methodologies presented in Appendix A of Palermo et al. (1998b) will be used to determine the stable armor stone particle size that would be resistant to erosion during return interval flood flow conditions. Equation 2 of Appendix A of Palermo et al. (1998b) will be used to predict the mean stable armor material stone size:

Equation 4-1

$$D_{50} = S_f C_s C_v C_T C_G d \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{\frac{1}{2}} \frac{V}{\sqrt{K_1 g d}} \right]^{2.5}$$

where:

D_{50}	=	mean stable armor material stone size (feet)
S_f	=	safety factor (assumed 1.1)
C_s	=	stability coefficient for incipient failure (assumed 0.375 for rounded stone)
C_v	=	velocity distribution (assumed 1.0)
C_T	=	blanket thickness coefficient (assumed 1.0 for flood flows)
C_G	=	gradation coefficient = $(D_{85} / D_{15})^{1/3}$
d	=	model-predicted water depth (feet)
V	=	model-predicted depth-averaged velocity (feet per second [fps])
γ_w	=	unit weight of water (62.4 pounds per cubic foot [lb/ft ³])
γ_s	=	unit weight of stone (assumed 165 lb/ft ³)
K_1	=	side slope correction factor (based on slope of the cap design and relation of the cap to the channel banks of the River)
g	=	gravitational constant (32.2 feet per second squared [ft/s ²])

In addition to the use of this equation, the Shield's diagram presented in Vanoni (1975) will also be used to predict the stable particle size based on the depth-averaged velocity. Both methods will be used to determine the appropriate stone size necessary for resistance to erosive forces due to river currents.

4.2.5.1.2 *Wind-generated Waves*

The Automated Coastal Engineering System (ACES) developed by USACE (1992) will be used to predict the 100-year return period wave height and estimate the stable armor stone size that will be resistant to the predicted wave height. The ACES employs both simple empirical models and complex mathematical models to estimate wave height. First, the 100-year return interval wind speed will be estimated based on nearby historical wind data provided by the closest and best representative National Climactic Data Center (NCDC) meteorological station. The NCDC historical wind gage data will be compiled into directional bins based on the reported wind direction. A statistical analysis of the historical wind gage data will be performed by applying five candidate probability distribution functions (Fisher-Tippet Type I and Weibull distributions with exponent k

varying from 0.75 to 2.0) fitted to the maximum yearly wind speed in each direction bin. The 100-year return interval event wind speed in each directional bin will then be used to predict the 100-year wave height and period. Only wind directions that could produce waves directed toward the cap will be evaluated. The fetch length and average water depth will be computed for these directions.

If the 100-year wave height is predicted to break over the cap (i.e., the cap is located in the surf zone), the rubble-mound revetment module with ACES (USACE 2004) will be used to compute the median armor stone size (D_{50}) based on the slope of the cap. Outside of the surf zone, with the 100-year wave traveling over the cap without breaking, the methodology outlined in Appendix A of Palermo et al. (1998b) will be used to estimate the median armor stone material (D_{50}) required to resist erosion due to the 100-year bed-level wave orbital velocities.

4.2.5.1.3 *Vessel-generated Waves*

Two separate analyses will be used to evaluate vessel-generated waves at the Final Project Area; the Bhowmik et al. (1991) methodology will be used for small recreational vessels, and the Weggel and Sorensen (1986) methodology will be used to evaluate large commercial vessels. A variety of representative recreational and commercial vessels that are known to operate or have the potential to operate near the cap will be evaluated for vessel-generated waves. The vessel-generated wave analysis presented in the Lower Willamette Group (LWG) draft FS (Anchor QEA 2012b) included pushboats, passenger ferries, fireboats, and jetboats as representative vessels and concluded that a passenger ferry should be used as the design vessel for the Final Project Area (Anchor QEA 2012b). For small recreation vessels, the Bhowmik et al. (1991) method predicts the wave height based on the vessel length, draft, traveling speed, and distance from the vessel to the point of interest (sailing line distance). The Bhowmik et al. (1991) wave height prediction equation is presented below:

Equation 4-2

$$H_m = 0.537V^{(-0.346)}x^{(-0.345)}L_v^{(0.56)}D^{(0.355)}$$

where:

H_m	=	wake wave height (meters [m])
V	=	vessel speed (m/s)
x	=	vessel sailing line (m)
L_v	=	vessel length (m)
D	=	vessel draft (m)

The Weggel-Sorensen (1986) model will be used to estimate the wave height generated by large commercial vessels as a function of the vessel speed, distance from the sailing line, water depth, vessel displacement volume, and vessel hull geometry. The predicted wave heights for the recreational and commercial vessels will then be used to predict the minimum stable armor material particle size using the ACES (USACE 2004) and Palermo et al. (1998b) methodologies as described for wind-generated waves above.

4.2.5.1.4 *Propeller Wash*

Representative vessels that operate at the Final Project Area will also be evaluated for potential propeller wash effects. The propeller wash analysis presented in the LWG draft FS (Anchor QEA 2012b) included varying vessel types and sizes expected to occur throughout the area as representative vessels and concluded that a small tug should be used as the design vessel for the Final Project Area (Anchor QEA 2012b). As a vessel or boat moves through the water, the propeller produces an underwater jet of water. This turbulent jet is known as propeller wash (or propwash). If this jet reaches the bottom, it can contribute to resuspension or movement of bottom particles. The model that will be used to predict potential propeller wash effects on the cap are outlined in Appendix A of Palermo et al. (1998b). Equation 6 from Appendix A of Palermo et al. (1998b) predicts the propeller velocity at any location below (z distance) and aft of (x distance) the vessel propeller.

Equation 4-3

$$V_x = 2.78 \times U_0 \times \frac{D_0}{x} \exp\left(-15.43 \left(\frac{z}{x}\right)^2\right)$$

where:

V_x	=	propeller wash velocity at location x and z (fps)
D_0	=	adjusted propeller diameter (function of propeller type and diameter)
x	=	horizontal distance aft of propeller (feet)
z	=	distance from axis of propeller (feet)
U_0	=	propeller wash jet velocity (fps) at the propeller (Equation 4) from Appendix A of Palermo et al. (1998b)

The values of x and z will be determined from the site-specific water depths and areas of vessel operation. The propeller wash velocity can then be used with Equation 5 from Palermo et al. (1998b) to empirically compute the minimum stable armor material stone size resistant to the propeller wash forces.

4.2.5.1.5 Filter Design

Based on the largest predicted median particle size (D_{50}) predicted by the erosion protection analysis, the design gradation curve will be computed based on the Engineering Manual 1110-2-2300 equations, summarized in the ACES technical manual (USACE 2004), which specify the gradation curve based on the known median particle diameter size. The standard geotechnical filter criteria presented by Terzaghi and Peck (1967) will be used to determine whether fine-grained underlying sediments or underlying cap material is susceptible to piping between void spaces of the overlying erosion protection armor layer. The Terzaghi minimum filter criteria suggests that five times the D_{85} (85 percent passing by weight sieve size) size of the underlying material should be greater than the D_{15} (15 percent passing by weight sieve size) of the overlying material, as shown below:

Equation 4-4

$$d_{15(Armor)} < 5d_{85(Base)}$$

where:

- $d_{15(armor)}$ = The 15 percent passing sieve size of the overlying armor material by weight
 $d_{85(filter)}$ = The 85 percent passing sieve size of the underlying material by weight

If the filter criteria (above) is not met (e.g., the second performance standard above is not met), an additional filter layer between the armor stone and the physical and/or chemical isolation layer of the cap will be required to prevent piping. The filter material will be designed as a well graded granular layer with intermediate particle sizes between the armor material particle sizes and the underlying sediment or cap layer particle sizes (likely sand). Depending on thickness restraints for the cap, the gradations of the cap physical and/or chemical isolation layer or the armor layer may be redesigned to fulfill the Terzaghi minimum filter criteria and eliminate the requirements for a separate filter layer.

Guidance for the thickness of the armor layer of the cap from Appendix A of Palermo et al. (1998b) will be used to determine the required thickness of the armor layer. As noted above, the largest diameter armor size determined for any of the four erosive forces will be used to determine the cap design. Generally, the minimum thickness of the cap armor layer is required to be at least 1 times the D_{100} dimension or 1.5 times the D_{50} dimension of the armor material selected. To be conservative, the thickness of the armor layer will likely be a minimum of the larger of 1.5 times the D_{100} dimension or 2 times the D_{50} dimension of the armor material.

4.2.5.2 Data Requirements and Data Gaps

The following data requirements and data gaps exist for the erosion protection analyses:

- **River Currents:** Detailed sediment bathymetry, upland topography, and estimated Manning's n roughness values both at the Final Project Area and, to the extent necessary, upstream and downstream will be used to support development of the hydraulic or hydrodynamic model. Historical daily-average flow rate data (U.S. Geological Survey [USGS] Portland gage No. 14211720) will be used to support the development of the hydraulic or hydrodynamic model boundary conditions. The upstream flow rates will be developed using the PeakFQ tool developed by USGS based on Bulletin #17B (USGS 1982), which determines the flood flow rates for various return interval flood events based on the Log-Pearson Type 3 flood frequency analysis of USGS Portland gage (No. 14211720) data. The water levels at the downstream boundary of the hydraulic or hydrodynamic model will be determined from Federal Emergency Management Agency Flood Insurance Studies (FIS) water surface elevation profiles for less frequent flood events (the 10-year, 50-year, and 100-year return interval flood events) and from available gage data for more frequent flood events (the 2-year flood event).
- **Wind-generated Waves:** Historical wind data (Portland International Airport from NCDC and the Meteorological Resource Center), fetch measurements (methodologies laid out in the *Coastal Engineering Manual* [USACE 2002]), and average water depths along each fetch, will be used to support the wind-generated wave analysis.
- **Vessel Traffic Information:** USACE website database on annual trips and drafts of vessels on the Lower Willamette River, USACE database on vessels residing in the Port of Portland, Port of Portland documents on arrivals and departures of all industrial vessels, and NW Natural information documenting lessee vessel traffic will be used to support the erosion evaluation. Both the vessel dimensions and operating speeds will be obtained.
- **Propeller Wash:** Vessel traffic information and vessel characteristics (propeller type, draft, and engine horsepower) for commercial and recreational vessels, operating conditions (including the propeller orientation and percentage of applied horsepower), the water depth over the cap, whether the vessel is not situated directly over the cap, and the horizontal distance between the vessel and the cap footprint will be used to support the propeller wash evaluation.

The last detailed bathymetry survey was performed in 2011. NW Natural will perform an additional bathymetry survey throughout the entire Final Project Area to support development of the remedial design documents with current elevation data. The last topography survey was performed in 2006 and 2011 (merged datasets). The topography has not changed substantially since these dates so NW Natural does not propose an updated topography survey to inform design elements associated with the riverbank.

4.2.6 *Element 4—Presence and Effect of Debris*

This technical element is generally recognized in sediment remediation guidance documents (EPA 2005; ITRC 2014) and is commonly evaluated and incorporated into cap designs. For example, Section 5.4.1.4 of *Contaminated Sediments Remediation* states, “In general, a sediment cap can be placed atop in-water infrastructure or debris” (ITRC 2014). Although debris (e.g., piling, old structure foundations, and concrete rubble), in many cases, can be relatively easily capped in place, its presence above the mudline surface in some instances can impact cap construction methods or performance and, therefore, requires assessment (EPA 2005). This assessment would determine whether exposed debris can be capped in place such that the cap is effective per the guidance design considerations (e.g., Figure 5) or if it must be removed at the mudline prior to capping. Additional site-specific considerations due to the presence of debris include potential limitations on construction methods, such as cap material placement methods or equipment.

The proposed performance standards related to debris are as follows:

- Demonstrate any debris present will not impact the performance of cap physical isolation and chemical isolation components or cap stability.
- If the debris is expected to impact cap performance, demonstrate the debris can be sufficiently removed to allow placement of an effective cap.

4.2.6.1 **Method of Analysis**

To evaluate the first performance standard, the embedment nature, and size of any debris present at the Final Project Area will be assessed relative to the thickness of the cap being placed and the geotechnical properties in the Final Project Area. A side scan sonar survey was performed within the Gasco Tar Removal Early Action Final Project Area in 2008, and NW Natural performed a site-specific high-resolution side scan survey in 2011 (Figure 7). Low-profile debris laying on the sediment surface that can be completely covered by the full-thickness of cap and effectively contained within the cap is not expected to impact the performance of the physical or chemical isolation. Alternatively, larger debris that would not be fully contained within the cap may impact the performance of the physical or chemical isolation and, therefore, require removal prior to capping. The specific thresholds established for debris that can be effectively capped without removal versus requiring removal prior to capping will be determined during design in coordination with the physical and chemical isolation (Element 1) and geotechnical stability (Elements 5 and 6) findings. Geotechnical impacts related to removal of cap penetrating debris will also need to be considered. For instance, removal of abandoned piling may reduce the stability of existing slopes where a cap is to be placed—a better alternative may be to cut the piling at or just below the mudline.

4.2.6.2 Data Requirements and Data Gaps

The likely extent of debris will be determined through review of the existing detailed 2011 bathymetry, the 2008 and 2011 side scan sonar surveys, drawings, photos, and other historical information. This review process will evaluate the following information:

- Debris material type (e.g., wood, brick, concrete, rock, metal, and vegetation)
- Debris size (e.g., length, width, and height above mudline)
- Debris embedment depth
- Debris relative shape and porosity (e.g., solid versus open structure)
- Mapping of abandoned pilings extending above the mudline and general condition (degree of weathering)

If deemed to be warranted based on the existing document review, additional debris characterization may be proposed using geophysical surveying methods (e.g., side-scan sonar and magnetometer surveys). The material type, approximate size, shape, and porosity of debris may also be further characterized by visual inspection of underwater video based on evaluation of the current identified debris in the Final Project Area.

4.2.7 *Element 5—Slope Stability*

Both the USACE (Palermo et al. 1998a) and EPA (Palermo et al. 1998b) guidance documents state that geotechnical considerations are important in capping because most contaminated sediments are fine-grained silts and clays. Fine-grained silts and clays are generally lower strength materials that are potentially susceptible to sliding slope failures following cap placement. A portion of the Final Project Area has fine-grained material, although the majority of the Final Project Area is coarser-grained sands. Proper assessment of the stability of slopes to support a cap is a critical geotechnical component in a cap design (Palermo et al. 1998a, 1998b; EPA 2005; ITRC 2014). Stable cap construction has been successfully completed at numerous sites, including sites within the Portland Harbor (e.g., Gasco Tar Body Early Action, McCormick and Baxter, and the Port of Portland's Terminal 4). The cap construction implemented at these sites, which followed appropriate slope stability design measures outlined in the capping guidance documents, provide useful precedents for potential slope stability performance standards.

The proposed performance standards for demonstrations of slope stability are as follows (Palermo et al. 1998b):

- Demonstrate the cap and slope will be stable after placement on slopes. Computed slope stability factors of safety with the placed cap shall meet the slope criteria established by USACE (2003).

4.2.7.1 Method of Analysis

Guidance for cap slope stability analysis methodologies are outlined in Appendix C of Palermo et al. (1998b). The first task is to select representative cross-sections of slope areas where capping is being evaluated at the Final Project Area. The cross-sections will be selected for representative conditions as well as steeper slopes. Slope stability will be evaluated using Rocscience SLIDE 6.0 computer software. The geometry and stratigraphy of existing or proposed slopes and associated corresponding soil and water parameters (e.g., groundwater elevations, river stage elevation, soil strength model, soil density, and soil strength) will be used as inputs, and trial runs will be conducted to locate the “critical” failure surface—that is, the failure surface with the lowest factor of safety (FOS). The software uses limit equilibrium methods to calculate stresses (loads) and strength (resistance) for each slip surface evaluated. The FOS is computed using methods that satisfy both force and moment equilibrium for the failure surface. The computed factors of safety for all failure surfaces will need to exceed the established performance standard FOS (presented in USACE 2003). If the lowest FOS is above the performance standard, then the proposed cap section should be stable. If there are any factors of safety below the performance standard, then the geometry of the slope and/or cap section need to be adjusted accordingly.

4.2.7.2 Data Requirements and Data Gaps

The following data will be needed to support the slope stability design calculations:

- Bathymetry and topography of the areas to be capped are available and will be used to determine existing slope configurations.
- Slope configurations for cap areas after partial dredging will be determined based on the design dredge prisms in those same areas, as necessary.
- The unit weight, groundwater levels, and strengths of existing sediments or soils within the cap areas will be based on existing and/or additional collected geotechnical explorations conducted in the cap areas.
- The unit weight and strength of cap materials will be estimated using standard references (FHWA 1997) applicable to the cap material that is expected to be used (e.g., upland quarry sand).
- Willamette River levels will be established based on statistical analysis of historical data. A sensitivity analysis will be completed on these water levels to evaluate the impact of river level on slope stability.

Of these data requirements, NW Natural will review the existing geotechnical data within proposed cap areas and determine if additional data is necessary to support remedial design.

4.2.8 *Element 6—Bearing Capacity*

As discussed above for Element 5, USACE (Palermo et al. 1998a) and EPA (Palermo et al. 1998b) guidance documents state that geotechnical considerations are important in capping because most contaminated sediments are fine-grained silts and clays. Materials with these characteristics are generally lower strength materials that are potentially susceptible to displacement during cap placement as a result of bearing capacity failure. Therefore, proper assessment of the ability of the underlying sediments to support a cap is a critical geotechnical component in a cap design (Palermo et al. 1998a, 1998b; EPA 2005; ITRC 2014). Construction of caps with appropriate bearing capacity design considerations consistent with capping guidance has been completed at several sites (Verduin and Lynch 2005). These examples provide useful precedents for potential performance standards and proven capping demonstration evaluations within the Final Project Area.

The proposed performance standard for demonstrations of bearing capacity is as follows (Palermo et al. 1998b):

- Demonstrate that sediments can support the weight of a cap and allow the cap to provide physical and contaminant isolation as designed.

4.2.8.1 **Method of Analysis**

As cap material is placed, it results in an unbalanced load wherever there are variations in cap thickness. The unbalanced load is typically largest along the edge of the cap lift where the difference is equal to the height of the lift. However, an imbalance can also occur in the interior of a cap if a variation in lift thickness occurs during placement.

Theoretically, there is a critical cap height difference (h) that will induce a differential load sufficient to cause a bearing capacity failure of the subgrade. This can occur at the edge of a capping area or at points within the capping area where the cap thickness increases over a relatively short distance (e.g., 10 to 20 feet or less). When this occurs, the cap material can become intermixed with contaminated sediment or underlying cap layers. The objective of a cap bearing capacity analysis is to determine the critical height difference for cap thickness and evaluate if this critical height is reasonable given typical cap construction techniques and experience with previous capping projects.

Appendix C of Palermo et al. (1998b) describes a method of assessing the stability of a cap placed on soft sediment. Refinements to this methodology are presented in a U.S. Army Engineer Research and Development Center Technical Note (Rollings 2000). The method is based on the bearing capacity theory applied to a shallow foundation on a subgrade, whereby the cap is considered a footing acting over a large area. In this case, the footing contact pressure is replaced by an equivalent surcharge based on the cap's effective unit weight and thickness as follows:

Equation 4-5

$$q = \gamma' h$$

where:

q	=	equivalent surcharge (pounds per square foot [psf])
γ'	=	effective (submerged) unit weight of cap (lb/ft ³)
h	=	cap lift thickness or differential in cap height (feet)

First, the ultimate bearing capacity will be calculated using the Terzaghi equations for local failure using undrained shear strengths measured by soil strength, as determined by field testing, laboratory testing, and/or correlations with commonly accepted published literature for soil properties. The undrained shear strength will represent the most critical short-term condition when the cap is first placed and before pore pressures are allowed to dissipate. Once the cap has been placed, consolidation of fine-grained sediments will occur, which will increase the shear strength of the sediment. Thus, the long-term stability of the cap against bearing capacity failure will be greater than the short-term stability. Terzaghi's equation:

Equation 4-6

$$q_{ult} = c * N_c$$

where:

q_{ult}	=	ultimate bearing capacity of sediment (psf)
c	=	cohesion (undrained shear strength) of soil (psf)
N_c	=	Bearing capacity factor (dimensionless) = 5.14 for continuous strip footing (Terzaghi and Peck 1967)

The allowable differential in cap thickness (i.e., lift thickness), h_{allow} , in feet, can be determined by combining the previous two equations and incorporating an appropriate FOS as follows:

Equation 4-7

$$h_{allow} = \frac{5.14 c}{FOS * \gamma'}$$

Traditionally, with upland foundation design, an FOS of 3 is applied for a bearing capacity analysis of a footing. An FOS of 3 is appropriate for rigid building foundations because it limits potentially damaging settlement that could impact a structure. Caps are very flexible elements that can tolerate much higher settlements than a rigid building. Because rigid structural stability is not a design consideration, and due to the short duration of construction, an FOS of 1.5 is considered appropriate for use for evaluating the design cap lift thickness. Subaquatic cap placement has been successfully demonstrated at multiple sites when designed using a bearing capacity FOS of 1.5.

The allowable (critical) cap lift thickness differential analysis will follow the EPA and USACE guidance and evaluate stability with three different methods, which are described below:

- **Deterministic Evaluation.** A deterministic evaluation will be performed using the bearing capacity equations presented above by treating the sand cap as equivalent to a footing bearing on a subgrade, which, in this case, was the sediment being capped.
- **Probabilistic Evaluation.** To better address foundation stability of the caps, a probabilistic analysis of cap bearing will be performed that incorporates the variability of the measured undrained shear strength of the sediment and other parameters. This method can account for the lower observed shear strengths that the deterministic approach does not consider. The approach will use a Monte Carlo simulation to evaluate the different input uncertainties. This probabilistic analysis will utilize the traditional foundation bearing capacity formula described above for the deterministic evaluation, but instead of using a fixed FOS, the probability of no failure (e.g., FOS greater than 1) will be predicted.
- **Comparison to Past Similar Capping Projects.** As a final quality assurance check on the deterministic and probabilistic theoretical calculations presented above, case histories from previously completed capping projects will be reviewed. Specifically, cap stability observations from the completed projects will be reviewed, and sediment shear strengths from the completed projects will be compared with the results from the Gasco Sediments Site. If sediments of similar or lesser strength than the Gasco Sediments Site were successfully capped, these examples will be used to supplement other evaluations that indicate that sediments within the Final Project Area can be successfully capped.

Assessment using these three lines of evidence will be used to determine the appropriate maximum cap thickness necessary to meet the bearing capacity performance standard.

4.2.8.2 Data Requirements and Data Gaps

The bearing capacity design calculations will require determination of the undrained shear strength of sediments within the area to be capped. As stated above, this information can be collected via field methods (e.g., vane shear test or standard penetration test blow counts), laboratory methods (e.g., triaxial strength tests), and/or correlations with commonly accepted published literature for soil

properties. The thickness and unit weight of the cap material layers will also be required based on the final design.

NW Natural will review the existing geotechnical data within proposed cap areas and determine if additional data is necessary to support remedial design.

4.2.9 Element 7—Treatment Requirements

Requirements for treatment layers in caps are not specifically addressed in capping guidance documents. Rather, the need for treatment layers is determined as part of the contaminant containment assessment completed using existing Final Project Area conditions and modeling (see Element 1 above).

If treatment may be appropriate in areas proposed for capping because of the presence of PTW or for other reasons, and if all nine other capping demonstration elements are met, the cap design in these areas will include evaluation of an active layer (e.g., organoclay or activated carbon). Modeling of the existing Final Project Area conditions will be used to determine minimum concentrations of active materials within the cap section in those areas (see Element 1 above).

The method of analysis, data requirements and data gaps for demonstrating the effectiveness of the active layer treatment will be consistent with capping demonstration Element 1 for chemical isolation. Appendix I of the Draft EE/CA (Anchor QEA 2012a) includes this type of demonstration for the addition of an active layer of organoclay and provides a template for the cap treatment requirement evaluation.

4.2.10 Elements 8 and 9—Habitat Impacts from Capping and Habitat Mitigation, As Necessary

Habitat impacts from remedial design options, including capping, are discussed in Section 4.9.

4.2.11 Element 10—Department of State Lands Authorization Requirements

This element is not specifically addressed in capping guidance documents but is commonly evaluated and incorporated into cap designs in the Portland Harbor Site. DSL manages submerged and submersible lands of the state's navigable waterway system. DSL-owned submerged aquatic lands exist on the Final Project Area shoreline. Any permanent capping or other remedial action requiring monitoring and/or maintenance on DSL-owned land will likely require obtaining some form of authorization from DSL to access the submerged land (Oregon Administrative Rule [OAR] 141-145). Of the four available authorizations offered by DSL for remediation purposes—access authorizations, easements, conservation easements, and leases—the most relevant under present circumstances is likely to be an easement.

4.2.11.1 Method of Analysis

DSL ownership boundaries will be obtained and compared to proposed remedial areas. DSL will be contacted to make a determination as to whether a land access authorization is required for the proposed cap; if so, NW Natural will work with DSL to obtain such an authorization. If DSL requires an easement or other authorization but does not grant it, then the performance standard is not met.

4.2.11.2 Data Requirements and Data Gaps

The location of DSL ownership boundaries at the Final Project Area, as well as the extent of any permanent remedial measures (e.g., cap placement), will need to be determined.

4.2.12 Operational Considerations

Although not included in the ten EPA-identified technical cap demonstration elements, cap design guidance documents (Palermo et al. 1998a, 1998b; see Figure 5) state that operational considerations should also be evaluated as part of cap demonstration. Operational considerations are practices and controls that may need to be implemented to ensure that the cap functions as designed and remains intact over time. These considerations may include planned monitoring and maintenance of the cap, restrictions on uses of the waterway at the cap area (e.g., establishment of a regulated navigation area), and other institutional controls.

Routine monitoring, maintenance, and repair (if needed) should be scheduled based on a design storm magnitude or interval or other trigger event. The ability to enforce site use restrictions in and around cap sites should be considered when evaluating the overall implementability of the cap. An Operations, Maintenance, and Monitoring Plan would be developed to provide guidance related to long-term monitoring and maintenance of the cap.

4.2.13 Basis of Design Technical Evaluation Memorandum Elements

The Basis of Design Technical Evaluation Memorandum will include at a minimum the following:

- Results of the evaluations presented in Elements 1 through 10 and operational considerations
- Identification of areas proposed for capping (both after dredging and without prior dredging)
- Evaluation of placement equipment (e.g., bucket types, conveyor belts)
- Cap material type and gradation
- Allowable chemical concentration goals for cap material
- Cap plans in both (plan view and cross sections), including offsets from structures and grading requirements for cap slope stability
- Lateral extents and thickness of cap layers, including any active treatment amendments
- Volumes of capping materials
- Erosion protection requirements and management of identified debris
- Sequencing of the work, including anticipated production rates

4.3 Dredging Evaluation

Dredging evaluations for the Final Project Area will be developed based on the performance standards and design objectives, dredge prism evaluations, and additional considerations presented in the following subsections. These evaluations apply to both in-water sediments and riverbank sediments. A summary of the data requirements and currently identified data gaps associated with this evaluation and a summary of the information that will be included in the Basis of Design Technical Evaluation Memorandum for this evaluation are also presented.

4.3.1 *Performance Standards and Design Objectives*

The performance standards for dredging include the following:

- Remove, to the extent practicable, contaminated sediment concentrations exceeding the ROD-identified RALs (Table 5) and sediments containing PTW-NAPL/NRC that are not shown to be suitable for capping using pre-design data. Removal throughout the dredge prism will be deemed complete when comparison of the pre- and post-construction bathymetry surveys identify the design dredge elevations or depths are achieved.
- Perform the dredging in a manner that minimizes, to the extent practicable, water quality exceedances of field parameters (turbidity, dissolved oxygen, pH, and temperature) and contingent chemical parameters outside the compliance boundary.
- Dredge sediments in a manner that minimizes dredging residuals and prevents recontamination of adjacent sediments.
- Dredge sediments in a manner that minimizes damage to existing structures, upland source control measures, and existing slopes.
- Document that the design dredge elevations or thickness are achieved through performance of pre- and post-construction bathymetry surveys.

The following design objectives will be used for areas and volumes where dredging is determined for the design (including riverbanks):

- Remove contaminated sediments to the full depth of contamination defined by the presence of PTW-NAPL/NRC and/or RAL exceedances identified during pre-design data collection. If removal of the full depth of contamination is infeasible, complete partial removal to the deepest feasible depth and place a cap over the remaining materials. Achievement of the design removal elevations and depths will be based on comparison of pre- and post-construction bathymetry surveys.
- Conduct the work consistent with Best Management Practices (BMPs) to minimize the movement of material with elevated chemical concentrations outside the Final Project Area or impacts to existing structures, upland source control measures, and/or existing slopes.

- Conduct the work consistent with BMPs to minimize dredging residuals and minimize recontamination of adjacent sediments outside the Final Project Area.
- Conduct the work consistent with the WQMP to minimize water quality impacts outside the compliance boundary.
- Conduct the work consistent with the Biological Opinion developed by NOAA Fisheries.

4.3.2 *Dredge Prism Evaluation*

The lateral extents of dredging throughout the Final Project Area will be evaluated based on the location of sediment contamination and the results of the site-specific capping demonstration evaluations described in Section 4.2. Previous evaluations performed in the Draft EE/CA (Anchor QEA 2012a) identified that capping in the navigation channel would be difficult or inefficient due to the generally shallow vertical depth of contamination and the need to maintain navigation dredge depths (along with reasonable safety factors). This finding is consistent with the ROD technology application decision tree determination of dredging for most navigation channel and FMD areas. Consequently, dredging of contaminated sediments requiring remediation in the navigation channel and FMD areas is likely to remain as the most feasible remedial technology for design. Outside the navigation channel and FMD area, dredging is expected to be performed in areas where capping is not shown to be protective or feasible following the methods in Section 4.2. Also, consistent with the ROD, dredging will not be performed under structures that are left in place, and as noted in Section 4.7, this will include necessary offsets to protect structural integrity.

The vertical extents of dredging will be defined consistent with the ROD technology application decision tree. Specifically, the ROD requires that dredging within the navigation channel extend to the deepest depth of identified PTW-NAPL/NRC and RAL (Table 5) exceedances (whichever is deeper), except if the depth is greater than the federally authorized navigation channel depth of -37.8 feet NAVD88 (-43 feet CRD) plus an EPA-defined buffer thickness plus the design cap thickness. Evaluations by NW Natural indicate the deepest depth of contamination in the navigation channel in the Final Project Area is shallower than this exception, so capping is unlikely in these areas. In the intermediate zone (defined as outside the horizontal limits of the navigation channel and FMD areas to the riverbed elevation of approximately -2 feet CRD), the ROD requires dredging of the full extents of PTW-NAPL/NRC and RAL (Table 5) exceedances to the deepest practicable depth. In the shallow zone (defined as shoreward of the riverbed elevation of approximately -2 feet CRD), the ROD requires dredging of PTW-NAPL/NRC and RAL (Table 5) exceedances to a maximum depth of 5 feet below mudline.

In the riverbank, the ROD allows for either dredging or capping, or a combination thereof, of PTW-NAPL/NRC and RAL exceedances. The ROD does not provide a defined elevation threshold, so NW Natural proposes using from the top of riverbank down to the elevation where the slope significantly lessens, which the currently bathymetry shows to be 6.8 feet CRD and 4.8 feet CRD adjacent to the

Gasco and Siltronic properties, respectively. The ROD does not require dredging to a defined thickness for the riverbank. Therefore, if the dredging evaluation selects dredging as the appropriate remedial technology on the riverbank, NW Natural will evaluate the depth of dredging using the analyses identified in Section 4.3.4.

4.3.3 Additional Considerations

Additional considerations that will help guide the dredge design evaluations are detailed in this section.

Site Physical Characteristics. The range of anticipated water depths and mudline elevations throughout the dredge prism will be evaluated to support selection of the appropriate dredging equipment, anticipated dredging production rates, and equipment access. Sediment geotechnical characteristics will be evaluated to support the design of stable side slopes between variable elevation or thickness dredge units and external side slopes. Slope stability analyses will also be evaluated using site physical characteristics. Core logs will be evaluated for the presence of bedrock or native material that may hinder dredging by conventional dredging equipment and require specialized equipment. The presence, density, and type of debris, both surficial and buried, will be evaluated using the existing side scan sonar data and core logs.

Vessel Traffic. The class of vessels using the navigation channel and accessing the fuel pipeline dock are detailed in Section 4.1. The dredge design evaluations will consider the need for dredge equipment to quickly move so as to not disrupt vessel traffic in the navigation channel and to allow NW Natural's tenant operations at the facility to continued uninterrupted during dredging activities.

Structures. Structures that will be left in place (see Sections 3.6 and 4.7), including the upland source control system components (see Section 3.6.3), may need special consideration to ensure dredging does not compromise the integrity of the structures. The dredging evaluation will consider the need for horizontal offsets from any structure left in place based on adjacent required removal depths.

Accessibility. Waterside access in the shallow portions of the Final Project Area is inherently linked to river water levels; therefore, water levels during the typical fish window (July 1 through October 31) will be evaluated to determine whether dredging equipment will be able to access shallow portions of the Final Project Area. The ability to access the shallow areas from the uplands will be evaluated as an alternative to in-water dredging in shallow areas. Access to the area behind the fuel pipeline dock and north and south access ramps will be evaluated for horizontal and vertical clearance during anticipated high water elevations. Spacing between bents and supports will be compared to typical and specialized dredging equipment dimensions.

4.3.4 *Methods of Analysis*

The development of the dredge plan takes into consideration technical feasibility and site use restrictions that may affect the feasibility of dredging certain areas. The following evaluations will guide the development of the dredge plan:

- Dredge prism development
- Dredging slope stability
- Methods to minimize residuals

The dredge prism will be developed using the following process:

- Identify the predetermined depth of contamination (i.e., bottom depth of sediments with PTW-NAPL/NRC and RAL exceedances) in all sediment core samples within the refined dredging footprint, which will be determined using methods detailed in Section 4.3.2 above.
- Develop the neatline dredge prism. Bound the contaminant distribution using a constructible mosaic of rectilinear dredging units with constant elevation, constant thickness, or constant slope. The dredging units will be a constructible width for the dredging equipment best suited for the Final Project Area conditions and depth of contamination to be removed. The engineering design process will also incorporate allowances for stable slope requirements, waterfront structures, utilities, obstructions, navigation requirements, and other constraints.
- In consideration of the dredging equipment best suited for the Final Project Area conditions, as well as the depth and extent of removal, determine an appropriate over-dredging allowance.

Evaluations will be performed, as described in Section 4.2.7.1, to identify areas within the Final Project Area where there exists the potential for slope instability if the impacted sediments are fully removed. If slope instability is determined to occur in the vicinity of upland and in-water structures, refinements will be made to the dredge prism. Otherwise, slope stability evaluations will determine stable external sideslopes and internal sideslopes between dredge units.

Methods to minimize dredge residuals are described by Patmont and Palermo (2007). An analysis of the potential post-dredging residual layer will be performed using standard mass balance equations and site-specific physical and chemical properties, as described by Patmont and Palermo (2007) and USACE guidance (2008a, 2008b). The need for sand cover will be determined based on the mass balance results. Amendments, such as organoclay or activated carbon, may be added to sand cover layers if they are determined to be required to contain residuals concentrations using methods described in Section 4.2.3.

4.3.5 Basis of Design Technical Evaluation Memorandum Elements

The Basis of Design Technical Evaluation Memorandum will include, at a minimum, the following:

- Identification of removal areas and the removal technology (given site conditions and anticipated disposal options, mechanical dredging is currently the preferred removal technology)
- Evaluation of bucket types will be completed and consider sediment characteristics and water depths. Anticipated support equipment will also be presented.
- Dredge prism(s) in both plan view and in cross sections, including offsets from structures and slopes as well as dredge cut slope angles, will be presented. Justifications for required offsets necessary from structures and slope for stability will be presented.
- Overdredge allowances given the equipment type and site conditions
- Identification of necessary dredging offsets from structures to avoid negative impacts
- Volumes for the dredge prism(s)
- Sequencing of the work, including anticipated production rates
- Residuals management approaches
- Construction quality control/quality assurance measures to confirm the dredge work
- BMPs to be followed during dredging
- Water quality monitoring procedures to monitor the dredging work

4.3.6 Data Requirements and Data Gaps

The primary dredging performance standard is to achieve removal of the full lateral and vertical extents of RAL exceedances and PTW-NAPL (documented using comparison of pre- and post-dredge bathymetry surveys) identified during pre-design data collection that is deemed unsuitable for capping. To support the dredge prism development, a few key pieces of information are required, including a sufficient density of surface and subsurface sediment samples analyzed for RAL chemicals and visually observed for the presence of PTW-NAPL, geotechnical information to support slope stability evaluations and offsets from structures, and structural information.

Review of the subsurface PTW-NAPL observations and chemical concentrations has resulted in the identification of several unbounded cores (i.e., the bottom sampled interval contains PTW-NAPL or RAL exceedances). NW Natural will evaluate the location of these cores relative to other data and the EPA SMA-delineation requirements discussed in Section 3.3 to determine the appropriate location and density of any additional sediment core locations to fully delineate the vertical extents of PTW-NAPL and RAL exceedances and refine the dredge prism. NW Natural will also evaluate the lateral density of existing cores to determine whether additional strategically located cores may support refinement of the dredge prism.

NW Natural will review the existing geotechnical data within proposed dredge areas and determine if additional data are necessary to support remedial design. Similarly, as discussed in Section 3.3, NW Natural will review the surface and subsurface sampling density within and surrounding the Interim Project Area to determine if additional cores are necessary to refine the area and/or whether vertically unbounded data exists for either PTW-NAPL or RAL exceedances that requires additional sample collection.

NW Natural will review the design and as-built drawings (where available) of the structures in the Final Project Area (discussed in Section 3.6) to determine the appropriate lateral offsets of dredging from structures left in place. NW Natural has collected detailed elevation data of the structures within the Final Project Area, so no elevation data gaps exist.

4.4 Riverbank Remedy Evaluation

NW Natural will perform the riverbank remedy evaluation consistent with the requirements in the ROD and Gasco Sediments Site SOW (EPA 2009). NW Natural interprets the ROD requirements for riverbank remediation as follows:

- Remediation may be needed where PTW-NAPL/NRC is present in the riverbank or riverbank sediment concentrations located below the ordinary high water (OHW) elevation exceed the RALs (Table 5).
- Remediation may be needed where riverbank soil concentrations located above the OHW elevation exceed the PRGs currently under development in coordination with DEQ as part of upland Gasco property FS.
- Remediation may be needed where riverbank erosion evaluations show the potential for sediment recontamination based on soil erosion or slope instability.
- Where riverbank remediation is required, the remedial technologies will be assigned based on an evaluation of the riverbank branch of the ROD technology application decision tree.
- Per the decision tree, monitoring is a suitable remedy in areas without PTW-NAPL/NRC, where existing erosion protection is shown to be adequate.

Based on these requirements, NW Natural will determine the need for riverbank remediation adjacent to the Gasco property based on evaluations of the presence of PTW-NAPL, ROD-identified RAL exceedances, exceedances of the PRGs to be identified in the upland Gasco property FS, the potential for sediment recontamination due to riverbank soil erosion, and riverbank slope stability for the remedy post-construction condition. The capping and dredging evaluations described in Sections 4.2 and 4.3, respectively, will then be conducted to determine the appropriate remedial technologies to be applied along portions of the riverbank where remediation is required.

The riverbank remedy for the Final Project Area will be developed based on the performance standards and design objectives, erosion evaluations, structure protection evaluations, presence of

PTW-NAPL, RAL and PRG exceedances, and integration with current and future source control systems presented in this Work Plan. A summary of the data requirements and currently identified data gaps associated with this evaluation and a summary of the information that will be included in the Basis of Design Technical Evaluation Memorandum is also presented below.

4.4.1 Performance Standards and Design Objectives

If capping is selected as the remedial technology, the performance standards and design objectives presented throughout Section 4.2 will apply. If dredging is selected as the remedial technology, the performance standards and design objectives presented in Section 4.3.1 will apply. If monitoring is selected as the remedial technology, the performance standards and design objectives will be consistent with those identified for cap erosion resistance identified in Section 4.2.5.

4.4.2 Erosion Evaluations

The riverbank erosion evaluation and data requirements and data gaps will be consistent with the cap erosion evaluations presented in Section 4.2.5.

4.4.3 Structure Protection Evaluations

The riverbank structure protection evaluation and data requirements and data gaps will be consistent with the cap erosion evaluations presented in Section 4.7.

4.4.4 Presence of PTW-NAPL/NRC and RAL and PRG Exceedances Evaluations

The ROD applies PTW-NAPL and PTW-NRC (discussed in Section 3.1) to the riverbank, as shown in the ROD technology application decision tree. However, the ROD does not evaluate or identify the presence of either of these forms of PTW in riverbanks throughout the Portland Harbor Site or the Gasco Sediments Site Interim Project Area. Therefore, NW Natural proposes to evaluate the presence of each of these forms of PTW using site-specific data. Due to the highly armored berm constructed along the entire riverbank adjacent to the Siltronic property, no subsurface cores or borings have been advanced through the riverbank and there is no direct means to obtain visual observations of PTW-NAPL. As discussed with EPA during a meeting on June 5, 2017, due to the lack of direct observations, consistent with the approach used in the Draft EE/CA (Anchor QEA 2012a), existing core and boring logs collected along the bottom and top of the riverbank, respectively, will be evaluated for the presence of PTW-NAPL based on visual observations of NAPL. The elevations of observed PTW-NAPL in the cores and borings will be evaluated for evidence of continuity between the uplands and riverbank. If continuity is indicated, NW Natural will assume that the riverbank contains PTW-NAPL and perform a PTW-NAPL/NRC evaluation consistent with the applicable capping demonstration evaluation methods identified in Section 4.2. Figure 2 presents all available

subsurface core and boring locations that will be used for this evaluation. The colored symbology indicates the presence of PTW-NAPL.⁶

The ROD does not identify chemical concentration thresholds that may trigger remediation along the riverbank. Therefore, NW Natural proposes to screen available sediment data collected on the riverbank below the OHW elevation (e.g., elevations that are typically inundated by the river) against the Alternative F RALs (Table 5) identified in the ROD. As shown on Figure 8, there is only one surface sediment sample location (GSM-14) collected along the bottom of the Siltronic riverbank, just below the bottom elevation of armor, while there are several isolated surface sediment samples located between the armor materials along the Gasco riverbank.

Consistent with the Gasco Sediments Site SOW (EPA 2009), any riverbank soil samples collected above the OHW elevation will be compared against the applicable upland PRGs currently under development by NW Natural in coordination with DEQ as part of the upland Gasco property FS. The need for remediation based on any identified exceedances will be determined in coordination with EPA and DEQ.

The current technology assignments identified in the ROD within the Interim Project Area include very deep dredging and associated layback along portions of the riverbank to facilitate stable grades. As part of the flexible ROD-identified technology application assignment analysis, NW Natural will evaluate this dredging assignment. One specific aspect of the current assignment that will be evaluated is whether this layback will lead to impacts to the existing HC&C system infrastructure (Section 3.6.3) and any proposed alignments of the conceptual design alternatives for the Fill WBZ remedy.

4.4.5 Basis of Design Technical Evaluation Memorandum Elements

The Basis of Design Technical Evaluation Memorandum will include at a minimum the following:

- Estimated vertical and lateral extents of PTW-NAPL and RAL exceedances in the riverbank
- Lateral extent of riverbank that passes the erosive evaluation identified in the ROD technology application decision tree
- Justification for the remediation technologies based on erosion and presence of contamination

4.4.6 Data Requirements and Data Gaps

The data requirements and data gaps for the riverbank remedy evaluation are identified in Section 4.2.5.2. As shown in Figure 2, sufficient data density exists to support evaluation of

⁶ Note that observations of PTW-NAPL identified in this figure may not be consistent with other maps and figures previously produced by NW Natural as part of the upland Gasco RI and FS because other forms of non-mobile petroleum contamination (e.g., pencil pitch and lampblack) do not represent the mobile PTW-NAPL identified in the ROD.

PTW-NAPL in the riverbank via the use of PTW-NAPL observations in bottom of riverbank cores and top of riverbank borings. However, the nearshore cores GP26 and C302 located downgradient of upland boring P-42 have a greater spatial separation than the other bottom and top of riverbank sample pairing distances. Therefore, NW Natural proposes to collect an additional core as close as possible to the toe of riverbank armor downgradient from boring P-42 to evaluate the presence of riverbank PTW-NAPL in this isolated area. This sample will be included in the Data Gaps Sampling and Analysis Plan.

4.5 Dredge Sediment Waste Handling and Transport Evaluation

The sediment handling and transport evaluation for the Gasco Sediments Site will be performed based on the performance standards and design objectives and methods of analysis presented in the following subsections. A summary of the data requirements and currently identified data gaps associated with this evaluation and a summary of the information that will be included in the Basis of Design Technical Evaluation Memorandum for this evaluation are also presented.

4.5.1 *Performance Standards and Design Objectives*

The performance standards for dredge sediment waste handling and transport include:

- Perform the handling and transport in a manner that minimizes, to the extent practicable, water quality exceedances of field parameters (turbidity, dissolved oxygen, pH, and temperature), and contingent chemical parameters outside the compliance boundary.
- Handle and transport sediments in a manner that minimizes loss of materials.

The following dredge sediment waste handling and transport design objectives will be used in the remedial design process:

- Conduct the work consistent with BMPs in order to minimize the loss of material with elevated chemical concentrations into unintended areas.
- Conduct the work consistent with the WQMP in order to minimize water quality impacts outside the compliance boundary.
- Conduct the work consistent with the Biological Opinion developed by NOAA Fisheries.

4.5.2 *Method of Analysis*

The following evaluations will be performed to support the design of dredge sediment waste handling and transport:

- **Haul barge loading.** Evaluations will be performed to identify BMPs to minimize the loss of dredge material loading on haul barges from the dredge bucket, how best to manage haul barges to minimize re-handling that could result in release of materials, and the types of available haul barges that are sealed to prevent release during transport.

- **Dewatering Amendment Addition.** Evaluations will be performed to determine the most efficient type and amount of dredge material dewatering amendment (e.g., Portland cement, fly ash, or lime kiln dust) and location(s) of addition (e.g., on the barge, at the offloading facility, etc.), where necessary to facilitate truck or rail transport to the disposal facility. As discussed in the Draft EE/CA (Anchor QEA 2012a), bench scale testing of dredge material has been performed and this data will be used to support the evaluation.
- **Offloading Facility.** There is currently no designated facility identified for offloading dredge sediments in the Portland Harbor Site. Evaluations will be performed to identify potential facilities that can be used for offloading dredge sediments from the Final Project Area. The evaluations will consider the capacity of the facility to accommodate the volume of dredge materials and the proximity and accessibility to water- and land-based transportation. These evaluations will also include an assessment of the equipment that would be used for the offloading, associated BMPs to minimize spillage, and the method for temporary storage of the dredge material pending loading into trucks or rail (if direct loading is infeasible).
- **Wastewater Management.** Evaluations will be performed to determine the methods for wastewater management on the haul barges, at the offload facility, and at the landfill (if required).
- **Truck and Rail Transport.** Evaluations will be performed to identify the range of available forms of upland transportation of dredge material from the offloading facility to the landfill.
- **Decontamination.** Consistent with the Gasco Sediments Site SOW (EPA 2009), evaluations will be performed to determine the methods for decontaminating workers and equipment during waste handling and transport.

4.5.3 *Basis of Design Technical Evaluation Memorandum Elements*

The Basis of Design Technical Evaluation Memorandum will include at a minimum the following:

- Identification of the transport, offloading, and hauling of dredge material, equipment, and procedures. Anticipated support equipment will also be presented.
- Upland transportation options to the landfill
- Locations of different handling facilities including schematics of facility
- Quantities of material to be handled and transported and additional materials needed for the work
- Water management measures necessary during transport and offloading
- Methods for mixing sediment with amendments, if required, and locations for performing sediment amendment
- Sequencing of the work including production rates for the different elements
- Construction quality control/quality assurance measures to confirm handling and transport
- BMPs to be followed during handling and transport

- Development of a transportation and disposal plan focused on the materials handling and transport
- Water quality monitoring procedures to monitor the handling and transport

4.5.4 Data Requirements and Data Gaps

The dredge sediment and waste handling evaluations will require the total volume of dredge sediments and locations of dredging (to support haul barge loading access evaluations), the anticipated excess water that will be generated during haul barge loading and transport to determine the type and amount of dewatering amendment(s), and potential properties that could be used for the offloading facility. There are no sampling and analysis data gaps associated with these data needs.

4.6 Waste Disposal Classification Evaluation

Waste disposal classification evaluations for the Final Project Area will be performed based on the performance standards and design objectives, dredge prism evaluations, and additional considerations presented in the following subsections. A summary of the data requirements and currently identified data gaps associated with this evaluation and a summary of the information that will be included in the Basis of Design Technical Evaluation Memorandum for this evaluation are also presented.

4.6.1 Performance Standards and Design Objectives

The performance standards for waste disposal include the following:

- Demonstrate that removed material is disposed of at appropriate EPA- and DEQ-approved waste facilities.
- Waste material characterization will be sampled both prior to construction and during construction at a frequency and density in accordance with the Gasco Sediments Site SOW (EPA 2009).

The following waste disposal design objectives will be used in the remedial design process:

- Determine waste disposal suitability for discrete sediment management units using pre-construction sampling data that will be verified by sampling of dredge material stockpiles (temporarily stored on land or on watertight haul barges) during construction.
- Allow for tiered use of additional treatment amendments and additional sampling of a dredge material stockpile that is deemed unsuitable for Subtitle D disposal based on initial stockpile sampling.

4.6.2 Material Disposal Testing Evaluations

The Gasco Sediments Site SOW (EPA 2009) provides specific detailed testing procedures for determining the waste disposal classification for all dredge materials impacted by MGP- and chlorinated solvent-related wastes from the Final Project Area. These procedures do not account for the management of sediment pesticide concentrations that may trigger additional handling and disposal requirements in accordance with federal- or state-listed pesticide waste rules. For MGP- and chlorinated solvent-related wastes, the potential waste disposal classifications include materials that are a Resource Conservation and Recovery Act hazardous waste ("Hazardous Waste"), materials that will be disposed at a Subtitle C facility as a non-hazardous waste ("Special Waste"), and materials that are neither Hazardous Waste nor Special Waste ("Cleanup Materials"). The excerpted SOW-defined evaluation for each material is provided below.

"The method to determine that MGP-related material should be managed as a Special Waste shall be based on the absence of TCE and associated chlorinated volatile organic compound (CVOC) chemicals and exceedance of TCLP [toxicity characteristic leaching procedure] criteria for any MGP-related constituent. If TCLP criteria are exceeded at the time the material leaves the Site, then the material shall be designated Special Waste and transported to a Subtitle C facility. If not, the material would be disposed of as Cleanup Material at a Subtitle D facility that meets the requirements described above. This method applies to both untreated and post treatment materials, if treatment is proposed. Consequently, an untreated material may meet this definition, but, upon treatment may be determined to no longer meet this definition. In the event that treatment, including treatment in barges, changes the definition, the material would no longer be designated a Special Waste.

The method to determine that sediments impacted only by TCE and associated CVOC chemicals contain F002 Hazardous Waste shall be based on concentrations of TCE, cis-DCE, trans-DCE, 1,1-DCE, and vinyl chloride that exceed DEQ-approved risk-based concentrations (RBCs) to be developed for incidental ingestion, dermal contact and inhalation by landfill workers. If TCE, 1,1-DCE or vinyl chloride are detected in dredged material at concentrations below these RBCs but the material exceeds TCLP criteria for TCE, 1,1-DCE or vinyl chloride, the material shall be designated as a characteristic Hazardous Waste. This method applies to both untreated and post treatment materials. If following treatment, including treatment in barges, the material no longer exceeds the RBCs or the TCLP criteria for TCE and associated CVOCs, the material would be determined not to contain F002 Hazardous Waste and not to be a characteristic Hazardous Waste. If the material is determined to contain F002 Hazardous Waste or to be a characteristic Hazardous Waste because of TCE and associated CVOCs it would be

disposed of at a Subtitle C facility. If not, the material would be disposed of as Cleanup Material at a Subtitle D facility that meets the requirements described above.

It is specifically recognized that commingling of TCE and associated CVOC chemicals with MGP-related constituents and materials occurs at the Site. Therefore, three scenarios are possible:

- If it is determined that the concentrations of TCE, cis-DCE, trans-DCE, 1,1- DCE, or vinyl chloride in the commingled material exceed DEQ-approved RBCs developed for the landfill exposure scenario, the material shall be designated as and disposed of as F002 Hazardous Waste.*
- If it is determined that TCE, 1,1-DCE, or vinyl chloride exceed TCLP criteria, the commingled material shall be designated and managed as Characteristic Hazardous Waste. If it is determined that one or more MGP-related constituents exceed TCLP criteria, the commingled material shall be designated and managed in accordance with applicable state hazardous waste laws.*
- If it is determined that the commingled material is not F002 Hazardous Waste and not a characteristic Hazardous Waste, then the material would be managed as Cleanup Material.*

In addition, exceedance of TCLP criteria for any chemical other than those associated with MGP-related material or TCE and associated CVOCs, would result in the material being designated characteristic Hazardous Waste. TCLP is a standardized simple leaching procedure that is promulgated by federal regulation (40 Code of Federal Regulations [CFR] §261.24) and is designed to approximately simulate contaminant mobility in landfill conditions.

Also, if material containing either type of chemicals meets the following additional definitions of characteristic waste, then it shall be designated and disposed of as a characteristic Hazardous Waste:

- Ignitability – Ignitable wastes are those that can create fires under certain conditions, are spontaneously combustible, or have a flash point less than 60 °C (140 °F) as defined in 40 CFR §261.21.*
- Corrosivity – Corrosive wastes are acids or bases (pH less than or equal to 2, or greater than or equal to 12.5) that are capable of corroding metal containers as defined in 40 CFR §261.22.*
- Reactivity – Reactive wastes are unstable under "normal" conditions. They can cause explosions, toxic fumes, gases, or vapors when heated, compressed, or mixed with water as defined in 40 CFR §261.23."*

Finally, the ROD indicates that state-listed hazardous wastes have been identified offshore of RM 7W. NW Natural understands that, as of February 2016, DEQ was still researching the issue of whether sediment offshore of the Arkema site would be designated a state-listed pesticide waste. NW Natural needs additional clarification from EPA and DEQ concerning the extent to which sediments impacted by DDx and removed from the Gasco Sediments Site Final Project Area contain state-listed hazardous wastes.

4.6.3 Dredge Material Testing Framework

The Gasco Sediments Site SOW (EPA 2009) identifies a tiered dredge material testing framework to determine dredge material classifications throughout the Final Project Area. This evaluation includes sampling and analysis of dredge material both prior to and during construction. The SOW requires subsurface sediment samples to be collected throughout the Final Project Area prior to construction from "management units" that represent a dredge volume up to 10,000 cubic yards. Existing sample coring information will be reviewed to determine whether and to what extent management units are appropriately identified in areas that are likely to be dredged. If units are not adequately characterized, additional design sampling may be proposed in select areas to fill such data gaps. Core samples (existing and additionally collected) will be evaluated using the description from Section 4.6.2 to determine the dredge material classification in each management unit. This classification will then be used to finalize the remedial design in terms of volumes of each type of designated waste.

In addition, the SOW requires tiered confirmatory dredge material testing during construction. The testing will be tiered and phased to minimize the potential for construction delays, while ensuring that appropriate disposal determinations have been made based on the pre-construction testing described above. The tiers of construction testing include the following:

- **Tier 1.** The first three barge loads will be tested by obtaining representative subsamples from the barge load and combining them into a composite sample. The exact number of and method of obtaining samples will be detailed in the design documents. Each of these three samples will be analyzed per the methods described in Section 4.6.2 on a quick turn around and results evaluated. If results are consistent with the pre-construction testing determinations for these management units and with EPA approval, one in every 10 subsequent barge loads will be tested in a similar manner.
- **Tier 2.** If the results of the next three tested barge loads (i.e., 1 in every 10 barge loads tested after a total of 30 barge loads have gone to disposal) are consistent with pre-construction testing determinations for these management units and with EPA approval, 1 in 20 subsequent barge loads will be tested in a similar manner thereafter.
- **Tier 3.** Continue testing 1 in 20 barge loads unless results are inconsistent with pre-testing determinations for the unit in question.

If at any tier of testing, results are inconsistent with pre-testing determinations, NW Natural will perform additional testing of subsequent barge loads per the next lower tier testing requirements. For example, if testing of materials as part of Tier 3 identifies a TCLP criteria exceedance, NW Natural will revert to Tier 2 testing for subsequent barge loads. If the results of the next three barge loads under Tier 2 testing do not exceed the TCLP criteria, NW Natural will proceed to Tier 3 testing. However, if any of these next three barge loads exceeds TCLP criteria, NW Natural will further revert to Tier 1 testing. Additional management of materials following an exceedance of TCLP criteria may include activities such as enhanced mixing of materials in the barge to increase sediment homogeneity, additional mixing to distribute any stabilization (treatment) materials, addition of more or different stabilizing materials, or a determination that certain dredge units should be re-designated for disposal.

4.6.4 Basis of Design Technical Evaluation Memorandum Elements

The Basis of Design Technical Evaluation Memorandum will include at a minimum the following:

- Proposed landfills for disposal of all classifications of dredge material
- Dredge material waste disposal classifications based on pre-construction sampling results
- Delineation of management units throughout the Final Project Area dredge prism
- Flow chart illustrating the barge tier sampling process
- Estimated disposal volumes for each waste classification and associated landfills

4.6.5 Data Requirements and Data Gaps

The primary pre-construction data requirements to determine the waste suitability of dredge materials are obtained through TCLP testing, comparison of bulk sediment concentrations to the RBCs for the landfill worker exposure scenario (for chlorinated solvent-related wastes), and any additional comparisons that are required based on clarification from EPA and DEQ concerning the extent to which sediments impacted by DDX and removed from the Gasco Sediments Site Final Project Area contain federal- or state-listed hazardous wastes. Site-specific TCLP was performed by NW Natural in 2004 during the 2005 Removal Action design characterization (Anchor 2004), in 2009 as part of a focused TCLP investigation (Anchor QEA 2010b), and in 2010 during the Project AIR (Anchor QEA 2010a) data gaps sampling. In addition, significant surface and subsurface sediment analyses have been performed. NW Natural is in the process of evaluating the subsurface sampling data density relative to maximum 10,000 cubic yard management units to determine if the existing data is sufficient or if additional data gaps sampling for TCLP or bulk sediment chemical analysis is required to complete the waste disposal suitability evaluation. To complete this data gaps and data needs evaluation, NW Natural needs clarification from EPA and DEQ concerning the extent to which sediments impacted by DDX and removed from the Gasco Sediments Site Final Project Area contain federal- or state-listed hazardous wastes.

4.7 Functional Structures Determination

The ROD (EPA 2017a) technology application decision tree indicates a determination should be made as to whether any given structure is “functional” to determine if a structure needs to be removed or left in place during implementation of the remedy and the appropriate remedial technology to be applied in the structure footprint. The ROD provides two supporting pieces of information for this determination. One, the technology application decision tree indicates that a functional structure is operating or used to stabilize the riverbank and has a service life greater than 50 years. Two, page 115 of the ROD indicates, “Structures may be removed to access contaminated media unless it can be demonstrated that the structure is permanent (e.g., not floating or movable), functional (e.g. not beyond its design life and/or in disrepair), or needed for current or future property and waterway use. Minor structures, such as outfalls, will be moved to accommodate dredging and capping when necessary.”

Where movement or removal of the structure is infeasible based on this definition, the technology application decision tree indicates capping will be applied underneath and adjacent (the degree to which will be determined during remedial design) to the structure. The following subsection describes NW Natural’s proposed methods for making the functional structure determinations in the ROD, including performance standards, design objectives, data requirements/gaps, and information to be included in the Basis of Design Technical Memorandum on this issue.

4.7.1 *Performance Standards and Design Objectives*

The performance standards for the functional structures determination include the following:

- Determine which structures within the Final Project Area pass are permanent, functional, or needed for current or future property and waterway use.

The following functional structure design objectives will be used in the remedial design process:

- Demonstrate that structures deemed permanent, functional, or needed are not impacted by the overall sediment remedy, while demonstrating that the remedy appropriately remediates contaminated sediments and meets the RAOs.

4.7.2 *Method of Analysis*

Per the ROD technology application decision tree and page 115 of the ROD, functional structures are defined as those that meet any of the following conditions:

- Currently operating
- Used to stabilize the riverbank
- Is functional (not beyond its design life or in disrepair, or has a service life greater than 50 years)

- Is permanent (e.g., not floating or movable)
- Is needed for current or future property and waterway uses

NW Natural will review each shoreline and in-water structure discussed in Section 3.6, respectively, against each of these conditions. Generally, it is expected that the fuel pipeline dock and mooring dolphins for that dock as well as the U.S. Moorings dock clearly meet these conditions. It is expected that the floating structures attached to the northern portion of the fuel pipe line dock do not meet these criteria (i.e., it can be temporarily relocated during remediation), as well as the dilapidated dock on the southern end of the Gasco property. These determinations will be detailed in the Basis of Design Technical Memorandum by step-wise comparison of each structure to each condition.

4.7.3 Basis of Design Technical Evaluation Memorandum Elements

The Basis of Design Technical Evaluation Memorandum will include at a minimum the following:

- Outcome of the functional structure determinations for each structure
- Plans for removal or temporary relocation and reinstallation of non-functional structures

4.7.4 Data Requirements and Data Gaps

As-built drawings and a structural survey (if required by EPA) will be used to assess the condition of each structure potentially impacted by the sediment remedy.

4.8 Water Quality Best Management Practices Evaluation

Short-term water quality impacts and residuals generation is associated with contaminated sediment dredging activities. These dredging impacts can be mitigated to some degree using operational and barrier control BMPs. Water quality BMP evaluations for the Final Project Area will be performed based on the performance standards and design objectives, available operational controls, and the implementability issues associated with barrier controls presented in the following subsections. A summary of the data requirements and currently identified data gaps associated with this evaluation and a summary of the information that will be included in the Basis of Design Technical Evaluation Memorandum for this evaluation are also presented.

4.8.1 Performance Standards and Design Objectives

The performance standards for water quality BMPs include the following:

- Implement sufficient water quality BMPs to achieve water quality criteria at the required point of compliance.

The following water quality BMP design objectives will be used in the remedial design process:

- Implement operation and barrier control BMPs that minimize the loss of particulate and elevated dissolved phase contaminant concentrations at the required point of compliance, while maintaining ongoing operations at the Gasco property and no adverse impacts to navigation within the federal navigation channel.

4.8.2 Operational Controls

Operational controls impose limitations on the operation of the equipment being used for removal activities. NW Natural will evaluate the use of the below list of available operational controls for environmental mechanical dredging that usually reduce resuspension and loss of contaminated sediments:

- Requiring a debris sweep prior to dredging in known debris areas (debris caught in dredging equipment can cause additional resuspension and release of contaminated sediments)
- Properly selecting the dredge bucket for site conditions (i.e., soft sediment versus debris or hard digging)
- Minimizing the potential for slope failures by maintaining stable side slopes during dredging (e.g., shallow top-to-bottom cuts)
- Slowing the rate of dredge bucket descent and retrieval (increasing dredge cycle time)
- Limiting operations during relatively high water velocity conditions (turbulence in the vicinity of the dredge bucket during high flow conditions can cause additional resuspension and release of contaminated sediments)
- Preventing "sweeping" or leveling by pushing bottom sediments around with dredge equipment to achieve required elevations
- Preventing interim stockpiling of dredge material on the river bottom
- Preventing the overfilling of conventional clamshell (i.e., "open") buckets
- Requiring the slow release of excess bucket water at the water surface
- Preventing over-filling of barges to minimize spillage from barges
- Separating sediment solids from barge return water through filtration

4.8.3 Barrier Controls

NW Natural will evaluate the following two primary engineered barrier controls at environmental dredging and capping sites (USACE 2008a):

- Silt curtains
- Rigid containment (e.g., sheetpile walls)

NW Natural will perform a literature search to gather empirical information about each of these engineered barrier controls, including performance data from multiple case studies exhibiting similar

characteristics as the Gasco Sediments Site. This research will include any empirical information on the following implementability issues encountered for implemented barrier controls:

- Release of highly concentrated contaminants sequestered within the containment area following removal of the containment barrier
- Scour along the bottom of the barrier
- Billowing of the barrier due to river currents
- Maximum water depth limitation
- Limitations on equipment access and egress
- Impacts to site operations
- Offsets from structures
- Anchoring stability
- Impacts of debris on installation
- Fish removal and exclusion
- Impacts to dredge production rate
- Impacts of floating debris
- Resuspension of buried contamination during retrieval
- Penetration of contamination to much deeper depths during installation
- Hazards and impacts to navigation

4.8.4 Basis of Design Technical Evaluation Memorandum Elements

The Basis of Design Technical Evaluation Memorandum will include at a minimum the following:

- Summarize case study performance data and implementability issues associated with operational and engineered controls.
- Summarize advantages and disadvantages of various operational and engineered controls.
- Evaluate the application of available operational and engineered controls at the Gasco Sediments Site and provide design recommendations, including any areas proposed to be enclosed by containment barrier technologies.

4.8.5 Data Requirements and Data Gaps

Existing empirical data for water quality operational and barrier control performance and implementability issues will be compiled and evaluated. This data will include the water quality BMPs implemented during the Gasco Sediments Site Tar Deposit Early Action.

4.9 Habitat Modification Evaluation

Habitat changes associated with remedy implementation will be evaluated for the Gasco Sediments Site remedy to demonstrate compliance with action- or location-specific ARARs, including but not limited to, the Clean Water Act Section 404(b)(1) (CWA 404[b][1]) and the Endangered Species Act

(ESA). There are other ARARs related to habitat and fish and wildlife that need to be considered. However, NW Natural assumes for this evaluation that CWA 404(b)(1) and ESA regulations will drive most habitat impact avoidance and mitigation decisions relevant to these other ARARs, although this will be verified in design. The CWA 404(b)(1) regulates discharge of fill into waters of the United States, and the ESA obligates federal agencies, in consultation with the U.S. Fish and Wildlife Service and/or NOAA Fisheries, to ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of any ESA-listed species or result in the destruction or adverse modification of designated critical habitat of such species.

The ROD provides some simple assumptions for minimizing habitat impacts, including the following:

- Intermediate region
 - The elevation of the top of the cap or residual layer will be no higher than the pre-design elevation to avoid loss of submerged aquatic habitat.
 - If appropriate to protect sensitive species, a habitat layer will be incorporated into the constructed remedy.
- Shallow region
 - The elevation of the top of the cap or residual layer will be no higher than the pre-design elevation to avoid loss of submerged aquatic habitat.
 - A habitat layer such as beach mix will be used for the final layer of clean cover in both residual management areas and capped areas to bring the surface back to the original (pre-dredge) elevation and to maintain the natural habitat.

These rules would be expected to improve habitats in some cases, but not necessarily in other cases, as described below. Possibly for this reason, the ROD clarifies, “The details of any necessary compensatory mitigation will be developed during remedial design” (page 105). The ROD further clarifies, “As part of the remedial design, EPA, in coordination with natural resource agencies and tribes, will determine what areas are considered in-river habitat areas and on the river bank for the purpose of complying with ESA and Section 404 of the CWA. EPA will also determine what elevations and what substrate materials will be required for caps, ENR, or placement of backfill materials in any identified habitat area to minimize adverse impacts to the aquatic environment while also ensuring that the material will remain in place” (page 113). Furthermore, in the ROD Responsiveness Summary, EPA states, “Where unavoidable temporary or permanent loss of habitat may occur from the cleanup, specific requirements for compensatory mitigation would be developed during remedial design. EPA intends to follow the recommendations of the NMFS [National Marine Fisheries Service], to the extent feasible, to avoid or minimize impacts on shallow water habitat. During remedial design, a detailed evaluation of area-specific conditions would be conducted. The ROD allows for flexibility in selection and design of remedial technologies based on information collected during remedial design” (page 2-67).

Accordingly, NW Natural proposes conducting a detailed design-level mitigation analysis for the Gasco Sediments Site. This habitat mitigation evaluation will compare existing habitat conditions in the Final Project Area to the conditions that would be present after remediation using Habitat Equivalency Analysis (HEA) and relative habitat values (RHVs) previously developed by EPA and other regulatory partners as part of the Portland Harbor Natural Resources Damage Assessment process (as in PHNRTC 2010). NW Natural believes such an approach should lead to mitigation plans consistent with NMFS recommendations, given that NMFS was heavily involved in discussions of a similar analysis that was conducted for the LWG draft FS (Anchor QEA 2012b). The results of the HEA and evaluation of potential effects to waters of the United States and ESA-listed species and critical habitat will be used to determine the requirements for compensatory mitigation to offset habitat modifications resulting from implementation of the remedial design. This approach can be used in an iterative fashion in the design, where the design details are modified to further reduce impacts and balance the habitat mitigation provided by the overall design, as needed. Regardless, the goal will be to comply with habitat ARARs and provide an acceptable level of habitat mitigation that is fully integrated into the remedial design.

The CWA 404(b)(1) analysis and ESA evaluation must account for all alterations potentially impacting habitat, and thus, the total effect on habitat of all the remedy components must be evaluated together. Implementing a remedial action may have positive, negative, or neutral effects on aquatic habitat resulting from changes in water depth (gains or losses in elevation) and substrate type (e.g., from fine-grained materials to coarse, or coarse to fine). Studies have shown that shallow water habitats provide functions, such as prey production and refugia from predators, that are important to many listed salmonids and aquatic species (NMFS 2005a, 2005b; NOAA 2005; ODFW 2005; PHNRTC 2008; Wydoski and Whitney 2003). Studies have also shown that, generally, fine-grained sandy substrate provides habitat for macroinvertebrates, which are typically important juvenile salmonid prey in most river systems and that juvenile salmon prefer smaller substrates, such as sand and gravel (Chapman and Bjornn 1969 as cited in Healey 1991).

The main activities that will affect aquatic habitat during implementation of a remedial action include placement of substrate material and dredging. Placing substrate material in deep water may provide better habitat by elevating the river bottom to a shallower elevation. This activity could potentially improve habitat value by raising the elevation in a given area from the intermediate region to the shallow region, even though this scenario does not conform to the design assumptions used in the ROD. Further, the material placement thickness in deeper areas might be increased beyond that needed to address the other technical elements, specifically to create more shallow water habitat. Similarly, by selecting substrate materials and sizes that provide habitat for benthos, material placement may improve habitat conditions for foraging as compared to existing substrates. Conversely, material placement that alters surface substrates (e.g., going from natural fines to large rock) may result in negative habitat impacts. Dredging could result in a conversion of silt material to

sand and gravel material with the removal of materials that have settled on top of native sediment and/or placement of a clean residuals cover layer. Consistent with the ROD (EPA 2017a) requirements, a clean surface layer of residuals management cover (i.e., a clean sand) will be placed throughout all dredge areas, which will generally provide improved habitat and food web benefits once the area is recolonized by benthic species.

Habitat impact evaluations for the Final Project Area will be performed based on the performance standards and design objectives and methods of analyses presented in the following subsections. A summary of the data requirements and currently identified data gaps associated with this evaluation and a summary of the information that will be included in the Basis of Design Technical Evaluation Memorandum for this evaluation are also presented.

4.9.1 Performance Standards and Design Objectives

The performance standards for the habitat modification evaluation include the following:

- Demonstrate that the overall remedy complies with requirements of the CWA 404(b)(1) and the ESA through preparation of a CWA 404(b)(1) Analysis and a Biological Assessment.

The following habitat modification design objectives will be used in the remedial design process:

- First and foremost, achieve a post-remediation overall habitat value (including all elements of water depth, substrate type, shoreline vegetation, and riverbank slope angle) that maintains or improves the pre-existing habitat value relative to the Final Project Area as indicated by the HEA analysis.
- While achieving the first objective and to the extent practicable, also:
 - Maintain the existing acreage of high value shallow water habitat or increase such habitat acreage over the Final Project Area. This does not necessarily prohibit inter-conversion of shallow and intermediate region habitat in any given area; the objective is to be met over the entire Final Project Area.
 - Maintain or improve the habitat substrate value over the entire Final Project Area, particularly in riverbank and nearshore areas.
 - Maintain or improve the acreage of riverbank and nearshore slopes that attain or approach the most valued slope angle.

4.9.2 Method of Analysis

HEA will be used to evaluate habitat modifications from remedial activities within the Final Project Area and to determine whether compensatory mitigation would be required to comply with the CWA Section 404(b)(1) and Section 7 of the ESA. HEA is an accounting technique for calculating the replacement of lost ecological services (defined as functions and values that a habitat provides) resulting from an impact (NOAA 1997; Ray 2009). It is a generalized method that can be used in any

type of habitat, including freshwater rivers and streams, salt marshes, seagrass beds, and coral reefs. An estimate of how much habitat to restore to replace lost ecological services is based on balancing the total amount of services lost with those supplied by restored habitat, including services lost while the restored habitat is maturing and while the damaged habitat is recovering. The main assumption associated with HEA is that a one-to-one tradeoff between services lost and gained is acceptable rather than a one-to-one tradeoff in resources (NOAA 2000). HEA incorporates the discount rate concept, which assumes that people place a greater value on services they can utilize today than those in the future. HEA has been used by the USACE on various projects around the country to calculate appropriate mitigation requirements to comply with the CWA 404(b)(1) regulations since 2002 (Ray 2009). Examples include scaling various types of salt marsh, coral reef, and other kinds of restoration to offset impacts associated with deepening and widening navigation channels and harbors and conversion of aquatic habitat to upland for the placement of dredged material.

For this analysis, HEA will include estimating the existing functional value of the Final Project Area aquatic habitat and the future functional value of the Final Project Area's aquatic habitat resulting from implementation of the remedy. The HEA will use habitat indicators and associated RHVs that have previously been applied to aquatic habitat in Portland Harbor. The HEA will be completed on discrete areas within habitat types defined by elevations, substrate types, and slopes, including those areas where habitat conversions occur as part of remedy implementation (e.g., shallow water to deep water). A HEA workbook template is provided in Appendix A. The specific input parameters that will be used for the analysis include the following:

- Habitat Categories—categories defined by elevations that will be used in this analysis include the following (Appendix B):
 - Riparian habitat—above OHW
 - Active Channel Margin—between OHW and ordinary low water (OLW)
 - Shallow Water (0-10)—between 0 and 10 feet below OLW
 - Shallow Water (0-20)—between 0 and 20 feet below OLW
 - Deep Water—deeper than 20 feet below OLW
- Pre- and Post-Remediation Relative Habitat Values—these inputs will use the RHVs developed by the Portland Harbor Natural Resources Trustees Council (PHNRTC) for the Natural Resource Damage Assessment process (PHNRTC 2010) that NMFS updated for ESA species (see Appendix B). If there are any habitat conditions that are not captured by these values, additional values will be developed in coordination with EPA and NMFS.
- Years to Fully Functioning Habitat—this post-remediation value will use the years to the full function RHV defined for a particular habitat type by the PHNRTC and NMFS, as shown in Appendix B.
- Base Year—this input will be defined as the year in which remedial construction, and thus the impact to habitat, is expected to occur.

- Discount Rate—a standard discount rate of 3 percent will be used, which is the value that is typically assumed in HEA.
- Number of Years the Project Exists—assume project will exist for 50 years (i.e., total project life).

The HEA results will be reported in discounted service-acre years (DSAYs). A DSAY represents the present value of all ecosystem services provided by 1 acre of the habitat in 1 year. The evaluation will compare the total number of DSAYs provided by the habitats in the Final Project Area, assuming no remedial activities during the project life, to the total number of DSAYs associated with the changes made to aquatic habitat resulting from implementing the remedial action. A net positive DSAY comparison indicates the post-remediation habitat is better than pre-remediation, even accounting for temporary impacts to habitats resulting from remedial activities, and that there is a habitat credit and no need for compensatory mitigation. A negative DSAY comparison indicates the post-remediation habitat is degraded compared to pre-remediation and that compensatory mitigation is needed. The amount of compensatory mitigation required (if needed) will depend on the type of mitigation proposed and the amount of DSAYs that can be generated per acre. If compensatory mitigation is necessary, a mitigation project type will be proposed and the size of the project will be scaled to match the DSAYs required to offset the habitat impacts.

The remedy design will evaluate design features that could be incorporated to avoid habitat modification and will describe the degree to which compensatory mitigation needs to be included as part of the overall remedial action to meet the substantive requirements of the CWA 404(b)(1) and ESA, and thus meet the performance standard. The design will be improved in an iterative fashion if necessary to achieve the habitat design objectives, while still achieving the remedy RAOs.

4.9.3 Basis of Design Technical Evaluation Memorandum Elements

The Basis of Design Technical Evaluation Memorandum will include at a minimum the following:

- Pre- and Post-Remediation Habitat Values and results of the HEA, and any relevant iterations that lead to the final post-remediation values
- Potential effects of remedial design to waters of the United States and ESA-listed species and critical habitat
- Compensatory mitigation incorporated into the design to offset habitat modifications otherwise resulting from implementation of the remedial design, if applicable

4.9.4 Data Requirements and Data Gaps

To accurately assess the value of existing and proposed habitat, additional data will be collected in advance of the remedial design. The Final Project Area bathymetry and the proposed sediment remedy design bathymetry of the submerged areas and riverbank areas will be used to determine

changes in water depth. A pre-remediation survey of the existing Final Project Area conditions will be conducted to assess the existing baseline habitat functions of the areas that will be remediated. This survey will include photographs and data collection to assess water depth, substrate type, shoreline slope, shoreline vegetation, habitat conditions, and the presence of shoreline structures and debris in the vicinity of the sediment remediation area.

4.10 Flooding Impact Evaluation

An evaluation will be conducted to ensure that the remedial design complies with federal and state floodplain management ARARs. To determine the net effect of the final remedy on flooding, the volume of material removed from the Final Project Area by dredging will be compared to the volume of material added by capping and/or material placement, including materials removed or placed to meet habitat design objectives discussed in Section 4.9. This “cut and fill balance” evaluation will serve as the primary determination of the likelihood of any flood impacts. However, if this screening evaluation indicates the fill exceeds the cut on a total net basis (i.e., the net fill balance is more than minimally positive), further evaluation may be needed in coordination with EPA, or the design may need to be modified. Modeling of flood water level changes is not proposed because it was found in the LWG draft FS (Anchor QEA 2012b) that the readily available and federally endorsed hydraulic models do not provide sufficient accuracy to make a no net flood rise determination for the 100-year flood event. The flooding impact evaluation will address the entirety of any proposed activity (e.g., sediment remediation and habitat mitigation and any other project elements) within the Final Project Area.

Flooding impact evaluations for the Final Project Area will be performed based on the performance standards and design objectives and methods of analyses presented in the following subsections. A summary of the data requirements and currently identified data gaps associated with this evaluation and a summary of the information that will be included in the Basis of Design Technical Evaluation Memorandum for this evaluation are also presented.

4.10.1 Performance Standards and Design Objectives

The performance standards for flooding impacts include the following:

- Demonstrate that the overall sediment remedy is not expected to cause a measurable increase in 100-year flood event by showing an overall balance of cut and fill or net positive cut.

The following flooding design objectives will be used in the remedial design process:

- To the extent feasible, design the sediment remedy such that the net dredge and material placement volumes balance or provide a net positive cut.

4.10.2 Method of Analysis

Consistent with the ROD (EPA 2017a), the total sediment remedy design net dredging and material placement balance will be determined. If the total fill volume of cap and other placed materials is comparable to or less than the total cut volume due to dredging and other removal activities, then the performance standard is met and flood flow impacts will not be further assessed. However, if the screening evaluation indicates the fill exceeds the cut on a total net basis (i.e., the net fill balance is more than minimally positive), further evaluation may be needed in coordination with EPA, or the design may need to be modified.

4.10.3 Basis of Design Technical Evaluation Memorandum Elements

The Basis of Design Technical Evaluation Memorandum will include the following:

- Dredging and material placement volumes across the Final Project Area
- A conclusion with regards to a balance of cut fill or positive cut being provided by the design

4.10.4 Data Requirements and Data Gaps

For the net cut and fill balance analysis for the overall remedy, the existing bathymetry of the Final Project Area (i.e., areas of proposed capping, dredging, and other mudline alterations), the design post-construction bathymetry, and the total remedy net cut and fill volumes will be used.

5 Sediment Remedy Basis of Design Technical Evaluation Memoranda

Following EPA approval of this Work Plan and completion of the subsequent EPA-approved data gaps field program, analysis, and reporting, NW Natural will develop and submit for EPA approval a series of memorandums that complete the EPA-approved technical evaluations using the updated dataset. Once the completed technical evaluations are approved by EPA, NW Natural will use the technical evaluation findings as the basis of design for preparing the site-specific preliminary, interim and final design for the Gasco Sediments Site.

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Tables

Table 1
ARARs for Remedial Action at the Gasco Sediments Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
Federal ARARs			
CWA, Section 404 and Section 404(b)(1) Guidelines	33 USC 1344 and 40 CFR Part 230	Regulates discharge of dredged and fill material into navigable waters of the United States.	Action-specific. Applicable to dredging, covering, capping, and designation and construction of in-water disposal sites and in-water filling activities in the Willamette River.
CWA, Section 304	33 USC 1313 and 1314 and most recent 304(a) list, as updated up to issuance of the ROD	Under Section 304(a), minimum criteria are developed for water quality programs established by states. Two kinds of water quality criteria are developed: one for protection of human health, and one for protection of aquatic life.	Chemical-specific and action-specific. Relevant and appropriate for cleanup standards for surface water and contaminated groundwater discharging to surface water if more stringent than promulgated state criteria. Relevant and appropriate to short-term impacts to surface water from implementation of the remedial action that result in a discharge to navigable water, such as dredging and capping if more stringent than promulgated state criteria.
CWA, Section 401	33 USC 1341 and 40 CFR Section, 121.2(a)(3), (4), and (5)	Any federally authorized activity which may result in any discharge into navigable waters requires reasonable assurance that the action will comply with applicable provisions of sections 1311, 1312, 1313, 1316, and 1317 of the CWA.	Action-specific. Relevant and appropriate to implementation of the remedial action that results in a discharge to the river if more stringent than state implementation regulations.
CWA, Section 402	33 USC 1342	Regulates discharges of pollutants from point sources to waters of the United States, and requires compliance with the standards, limitations, and regulations promulgated per Sections 301, 304, 306, 307, and 308 of the CWA.	Relevant and appropriate to remedial activities that result in a discharge of pollutants from point sources to the river if more stringent than state promulgated point source requirements.
Safe Drinking Water Act	42 USC 300f and 40 CFR Part 141, Subpart O, App. A. 40 CFR Part 143	Establishes national drinking water standards to protect human health from contaminants in drinking water	Chemical-specific. Relevant and appropriate as a performance standard for groundwater and surface water which are potential drinking water sources.
RCRA	40 CFR 260 and 261	Establishes identification standards and definitions for material exempt from the definition of a hazardous waste.	Action-specific. Applicable to characterizing wastes generated from the action and designated for off-site or upland disposal; potentially relevant and appropriate for use in identifying acceptance criteria for confined in-water disposal.
RCRA – Solid Waste	40 CFR 257 Subpart A	RCRA Solid Waste requirements may be relevant and appropriate to remedial actions that result in upland or in-water disposal of dredged material. Requirements for the management of solid waste landfills may be relevant and appropriate to upland disposal.	Location-specific. RCRA Solid Waste requirements may be relevant and appropriate to remedial actions that result in upland or in-water disposal of dredged material. Requirements for the management of solid waste landfills may be relevant and appropriate to upland disposal.
Hazardous Materials Transportation Act	49 USC § et seq. and 40 CFR Parts 171-177	Hazardous Materials Transportation Act requirements are applicable to remedial actions that involve the transport of hazardous materials (i.e., dredged material)	Action-specific. Applicable to dredging that requires upland disposal.
Fish and Wildlife Coordination Act Requirements	16 USC 662 and 663 and 50 CFR 6.302(g)	Requires federal agencies to consider effects on fish and wildlife from projects that may alter a body of water and mitigate or compensate for project-related losses, which include discharges of pollutants to water bodies.	Action-specific. Potentially applicable to determining impacts and appropriate mitigation, if necessary, for effects on fish and wildlife from filling activities or discharges from point sources.
Magnuson-Stevens Fishery Conservation and Management Act	50 CFR Part.600.920	Evaluation of impacts to EFH is necessary for activities that may adversely affect EFH.	Location-specific. Potentially applicable if the removal action may adversely affect EFH.
FEMA	44 CFR 60.3(d)(2) and (3)	FEMA contains flood rise requirements that are considered relevant and appropriate requirements for remedial actions.	Location and action-specific. Capping and work within the floodplain can not result in a significant decrease in flood capacity.
River and Harbors Act	33 USC 401 et seq. and 33 CFR parts 320 to 323	Section 10 prohibits the unauthorized obstruction or alteration of any navigable water. Structures or work in, above, or under navigable waters are regulated under Section 10.	Action-specific. Applicable requirements for how remedial actions are taken or constructed in the navigation channel.
Clean Air Act	42 USC §7401 et seq.	Establishes limits for air emissions from a range of sources including vehicles and industrial processes.	Action-specific. Applicable to remedial activities that generate air emissions.
TSCA	15 USC §2601 et seq.	TSCA requirements are applicable to contaminated material or surface water with PCB contamination	Chemical-specific and location-specific. May apply to remedial actions proposed for locations with PCB contamination at certain concentrations.

Table 1
ARARs for Remedial Action at the Gasco Sediments Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
Marine Mammal Protection Act	16 USC §1361 et seq. and 50 CFR 216	Makes it unlawful to take any marine mammal. "Take" is defined as pursuing, hunting, wounding, killing, capturing, trapping, and collecting.	Action-specific. Applicable to remedial actions that have the potential to affect marine mammals.
Migratory Bird Treaty Act	16 USC §703 and 50 CFR §10.12	Makes it unlawful to take any migratory bird. "Take" is defined as pursuing, hunting, wounding, killing, capturing, trapping, and collecting.	Action-specific. Applicable to remedial actions that have the potential to effect a taking of migratory birds.
National Historic Preservation Act	16 USC 470 et seq. and 36 CFR Part 800	Requires the identification of historic properties potentially affected by the agency undertaking, and assessing the effects on the historic property and seeking ways to avoid, minimize, or mitigate such effects. Historic property is any district, site, building, structure, or object included in or eligible for the National Register of Historic Places, including artifacts, records, and material remains related to such a property.	Action-specific. Potentially applicable if historic properties are potentially affected by remedial activities.
Archeological and Historic Preservation Act	16 USC 469a-1	Provides for the preservation of historical and archeological data that may be irreparably lost as a result of a federally approved project and mandates only preservation of the data.	Action-specific. Potentially applicable if historical and archeological data may be irreparably lost by implementation of the remedial activities.
Native American Graves Protection and Reparation Act	25 USC 3001-3013 and 43 CFR 10	Requires federal agencies and museums that have possession of or control over Native American cultural items (including human remains, associated and unassociated funerary items, sacred objects, and objects of cultural patrimony) to compile an inventory of such items. Prescribes when such federal agencies and museums must return Native American cultural items. "Museums" are defined as any institution or state or local government agency that receives federal funds and has possession of, or control over, Native American cultural items.	Location-specific and action-specific. If Native American cultural items are present on property belonging to the DSL that is a part of the removal action area, this requirement is potentially applicable. If Native American cultural items are collected by an entity which is either a federal agency or museum, then the requirements of the law are potentially applicable.
Endangered Species Act	16 USC 1531 et seq. and 50 CFR 17	Actions authorized, funded, or carried out by federal agencies may not jeopardize the continued existence of endangered or threatened species or adversely to avoid jeopardy or take appropriate mitigation modify or destroy their critical habitats. Agencies are to avoid jeopardy or take appropriate mitigation measures to avoid jeopardy.	Action-specific. Applicable to remedial actions that may adversely impact endangered or threatened species or critical habitat that are present at the site.
Executive Order for Wetlands Protection	Executive Order 11990 (1977), 40 CFR 6.302 (a), and 40 CFR Part 6, App. A	Requires measures to avoid adversely impacting wetlands whenever possible, minimize wetland destruction, and preserve the value of wetlands.	Location-specific. Relevant and appropriate in assessing impacts to wetlands, if any, from the response action and for developing appropriate compensatory mitigation for the project.
Executive Order for Floodplain Management	Executive Order 11988 (1977), 40 CFR Part 6, App. A, and 40 CFR 6.302 (b)	Requirements for Flood Plain Management Regulations Areas requires measures to reduce the risk of flood loss, minimize impact of floods, and restore and preserve the natural and beneficial values of floodplains.	Location-specific. Relevant and appropriate for assessing impacts, if any, to the floodplain and flood storage from the response action and developing compensatory mitigation that is beneficial to floodplain values.
National Flood Insurance Act and Flood Disaster Protection Act	42 USC 4001 et seq. and 44 CFR National Flood Insurance Program Subpart A	Requirements for Flood Plain Management Regulations Areas Requires measures to reduce the risk of flood loss, minimize impact of floods, and restore and preserve the natural and beneficial values of floodplains.	Location-specific. Relevant and appropriate for assessing impacts, if any, to the floodplain and flood storage from the response action and developing compensatory mitigation that is beneficial to floodplain values.

Table 1
ARARs for Remedial Action at the Gasco Sediments Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
State ARARs			
Oregon Environmental Cleanup Law ORS 465.315	Oregon Hazardous Substance Remedial Action Rules OAR 340-122-0040(2)(a) and (c) and 0115(3),(32), and (51)	Sets standards for degree of cleanup required, including for oil and other petroleum products/wastes. Establishes acceptable risk levels for human health at 1x10-6 for individual carcinogens, 1x10-5 for multiple carcinogens, and Hazard Index of 1 for noncarcinogens; and protection of ecological receptors at the individual level for threatened or endangered species and the population level for all others. OAR 340-122-0040 and 0115(3).	Chemical-specific. A risk-based numerical value that, when applied to site-specific conditions, will establish concentrations of hazardous substances that may remain or be managed on site in a manner avoiding unacceptable risk.
Oregon Environmental Cleanup Law ORS 465.315	OAR 340-122-and (b), 340-122-0040(4) 0115(32)	For hot spots of contamination in water, requires treatment, if feasible, when treatment would be reasonably likely to restore or protect beneficial uses within a reasonable time. For hot spots of contamination of sediments, requires treatment or excavation and off-site disposal of hazardous substances if treatment is reasonably likely to restore or protect such beneficial uses within a reasonable time.	Chemical-specific and action-specific. When contaminant concentrations fall within the definition of “hot spot” set forth in subpart 0115(32), treatment (including excavation and off-site disposal) of contaminated media to levels below such risk levels or beneficial-use impacts needs to be evaluated in the FS.
Hazardous Waste and Hazardous Materials II	ORS 466.005(7) OAR 340-102-0011 - Hazardous Waste Determination	Defines "Hazardous Waste" and the rule contains the criteria by which anyone generating residue must determine if that residue is a hazardous waste.	Chemical-specific and action-specific. Specifies substantive requirements if remedial action will involve on-site treatment, disposal, or storage of RCRA-listed or characteristic hazardous waste. (Note: off-site treatment, storage, or disposal subject to all administrative and substantive state requirements.)
Identification and Listing of Hazardous Waste	OAR 340-101-0033	Identifies additional residuals that are subject to regulation as hazardous waste under state law.	Action-specific. Specifies requirements if remedial action will involve on-site treatment, disposal, or storage of additional listed wastes.
Solid Waste: General Provisions	Specific regulatory references to be provided by DEQ when alternatives are identified for FS analysis	Substantive requirements for the location, design, construction, operation, and closure of solid waste management facilities.	Action-specific. Applicable if upland disposal facility contemplated on site for solid, nonhazardous, waste disposal, handling, treatment, or transfer. (Note: off-site transfer, treatment, handling, or disposal subject to all administrative and substantive state requirements.)
Solid Waste: Land Disposal Sites Other than Municipal Solid Waste Landfills	Specific regulatory references to be supplied by DEQ	Requirements for the management of solid wastes at land disposal sites other than municipal solid waste landfills.	Action-specific. Applicable to the on-site management and disposal of contaminated sediment, soil, and/or groundwater.
Water Pollution Control Act ORS 468B.048	Water Quality Standards OAR 340-041-0340, Table 20 and Table 33A	DEQ is authorized to administer and enforce CWA program in Oregon. DEQ rules designate beneficial uses for waterbodies and narrative and numeric water quality criteria necessary to protect those uses. OAR 340-041-0340 designates and defines the beneficial uses that shall be protected in the Willamette Basin. For the purposes of state law, Table 20 are the applicable criteria, unless there is a corresponding criterion under Table 33A, in which case Table 33A is applicable. (Note: if Oregon promulgates new criteria prior to ROD, such new criteria will be ARAR).	Chemical-specific and action-specific. Applicable to any discharges to surface water from point sources, groundwater, overland flow of stormwater, and activities that may result in discharges to waters of the state, such as dredge and fill, de-watering sediments, and other remedial activities. Relevant and appropriate as performance standards for sites and where contaminants are left in place.
Water Pollution Control Act ORS 468B.048	Regulations Pertaining to NPDES Discharges Specific regulatory references to be supplied by DEQ	Effluent limitations and management practices for point-source discharges into waters of the State (otherwise subject to NPDES permit but for on-site permit exemption).	Chemical-specific and action-specific. Applies state water quality standards and effluent limitations to point-source discharges to the Willamette River.

Table 1
ARARs for Remedial Action at the Gasco Sediments Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
Certification of Compliance with Water Quality Requirements and Standards	ORS 468b.035	Provides that federally approved activities that may result in a discharge to waters of the State require evaluation whether an activity may proceed and meet water quality standards with conditions, which if met, will ensure that water quality standards are met.	Action-specific. Applicable to implementation of the remedial action (e.g., dredging, capping, and construction of confined disposal facility) that may result in a discharge to waters of the State.
Rules Governing the Issuance and Enforcement of Removal-Fill Authorizations within Waters of Oregon Including Wetlands	OAR 141-085 0680, 141-085-0695, 141-085-0710, and 141-085-0765	Substantive requirements for dredge and fill activities in waters of the State, including in designated Essential Indigenous Anadromous Salmonid Habitat.	Action-specific. Applicable to remedial action dredge and fill activities, capping, and riverbank remediation.
Oregon Department of Fish and Wildlife Fish Management Plans for the Willamette River	OAR 635, div 500	Provides basis for in-water work windows in the Willamette River.	Action-specific. Potentially applicable to timing of implementation of the remedial action due to presence of protected species at the site.
Oregon Air Pollution Control ORS 468A et. seq.	General Emissions Standards OAR 340-226	DEQ is authorized to administer and enforce Clean Air program in Oregon. Rules provide general emission standards for fugitive emissions of air contaminants and require highest and best practicable treatment or control of such emissions.	Action-specific. Applicable to remedial actions taking place in on-site uplands. Could apply to earth-moving equipment, dust from vehicle traffic, and mobile-source exhaust, among other things.
DSL Remediation Lease	Rules Governing the Management of State-Owned Submerged and Submersible Land Subject to Remediation and Habitat Restoration Activities	DSL is authorized by the State to issue a lease or easement to a private party for the use of submerged lands for remediation projects.	Action-specific and location-specific. Applicable to remedial activities requiring short- and long-term access to DSL-owned submerged aquatic lands.
Oregon Air Pollution Control ORS 468A et. seq.	Fugitive Emission Requirements OAR 340-208	Prohibits any handling, transporting, or storage of materials, or use of a road, or any equipment to be operated, without taking reasonable precautions to prevent particulate matter from becoming airborne. These rules for “special control areas” or other areas where fugitive emissions may cause nuisance and control measures are practicable.	Action-specific. Applicable to remedial actions taking place in on-site uplands. Could apply to earth-moving equipment, dust from vehicle traffic, and mobile-source exhaust, among other things.
Indian Graves and Protected Objects	ORS 97.740-760	Prohibits willful removal of cairn, burial, human remains, funerary object, sacred object, or object of cultural patrimony. Provides for reinternment of human remains or funerary objects under the supervision of the appropriate Indian tribe. Proposed excavation by a professional archeologist of a native Indian cairn or burial requires written notification to the State Historic Preservation Officer and prior written consent of the appropriate Indian tribe. Prohibits persons from excavating, injuring, destroying, or damaging archeological sites or objects on public or private lands unless authorized.	Location-specific and action-specific. Potentially relevant and appropriate if archeological material encountered.
Archeological Objects and Sites	ORS 358.905-955 and ORS 390.235	Imposes conditions for excavation or removal of archeological or historical materials.	Location-specific and action-specific. Potentially relevant and appropriate if archeological material encountered.
Survival Guidelines	OAR 635-100-0135	Survival Guidelines are rules for state agency actions affecting species listed under Oregon's Threatened or Endangered Wildlife Species law.	Action-specific and location-specific. Substantive requirements of Survival Guidelines relevant and appropriate to remedial activities affecting state-listed species.
DEQ Guidance on Bioaccumulative Chemicals in Sediment.	DEQ, 2007. <i>Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment.</i>	Describes a process to evaluate chemicals found in sediment for their potential contribution to risk as a result of bioaccumulation. Provides alternative methods for developing sediment screening levels and bioaccumulation bioassay data.	To be considered: in level of cleanup or standard of control that is protective.

Table 1
ARARs for Remedial Action at the Gasco Sediments Site

Regulation	Citation	Criterion/Standard	Applicability/Appropriateness
Local ARARs			
City of Portland Land Use and Zoning	Title 24	The provisions of this Chapter shall regulate development and construction in flood hazard areas; land classified in a flood hazard area may restrict or affect uses and development permitted in one or more of the regular zones; requires balance of cut and fill in flood hazard areas.	Action-specific and location-specific. Remedial alternatives that require cut and fill within the Willamette River need to demonstrate balance of cut and fill (e.g., no net rise).
City of Portland Land Use and Zoning	Title 19	Zoning and land use determine current and future potential uses of property within the City of Portland. The City has jurisdiction adjacent to the shoreline, above the OHW line.	Action-specific and location-specific. Remedial alternatives that require work above the OHW line will need to be reviewed for land use compatibility by the City (Greenway).

Notes:
ARARs: Applicable or Relevant and Appropriate Requirements
CFR: Code of Federal Regulations
CWA: Clean Water Act
DEQ: Department of Environmental Quality
DSL: Department of State Lands
EFH: Essential Fish Habitat
FEMA: Federal Emergency Management Act
FS: feasibility study
NPDES: National Pollutant Discharge Elimination System

OAR: Oregon Administrative Rule
OHW: ordinary high water
ORS: Oregon Revised Statute
PCB: polychlorinated biphenyl
RCRA: Resource Conservation and Recovery Act
ROD: Record of Decision
TSCA: Toxic Substances Control Act
USC: United States Code

Table 2
ROD-Identified Cleanup Levels

Contaminant	Surface Water				Groundwater				Riverbank Soil/Sediment				Fish Tissue			
	Unit	Concentration	Basis	RAO	Unit	Concentration	Basis	RAO	Unit	Concentration	Basis	RAO	Unit	Concentration	Basis	RAO
Aldrin	µg/L	0.00000077	A	3					µg/kg	2	R	9	µg/kg	0.06	R	2
Arsenic	µg/L	0.018	A	3	µg/L	0.018	A	4	mg/kg	3	B	1	mg/kg	0.001	R	2
Benzene					µg/L	0.44	A	4								
BEHP	µg/L	0.2	A	3					µg/kg	135	R	9	µg/kg	72	R	2
Cadmium					µg/L	0.091	A/R ^a	8	mg/kg	0.51	R	5				
Chlordanes	µg/L	0.000081	A	3					µg/kg	1.4	R	5	µg/kg	3	R	2
Chlorobenzene					µg/L	64	R	8								
Chromium	µg/L	100	A	3	µg/L	11	A	8								
Copper	µg/L	2.74	A	7	µg/L	2.74	A/R	8	mg/kg	359	R	5				
Cyanide					µg/L	4	A	4								
DDx	µg/L	0.01	R	7	µg/L	0.001	A	8	µg/kg	6.1	R	9	µg/kg	3	R	2
DDD	µg/L	0.000031	A	3	µg/L	0.000031	A	4	µg/kg	114	R	5				
DDE	µg/L	0.000018	A	3	µg/L	0.000018	A	4	µg/kg	226	R	9				
DDT	µg/L	0.000022	A	3	µg/L	0.000022	A	4	µg/kg	246	R	5				
1,1-Dichloroethene					µg/L	7	A	4								
cis-1,2-Dichloroethene					µg/L	9.9	A	4								
Dieldrin									µg/kg	0.07	R	9	µg/kg	0.06	R	2
2,4-Dichlorophenoxyacetic acid					µg/L	70	A	4								
Ethylbenzene	µg/L	7.3	R	7	µg/L	7.3	R	8								
Hexachlorobenzene	µg/L	0.000029	A	3									µg/kg	0.6	R	2
Lindane									µg/kg	5	R	5				
Lead					µg/L	0.54	A/R	8	mg/kg	196	R	5				
Manganese					µg/L	430	R	4								
MCPP	µg/L	16	R	3												
Mercury									mg/kg	0.085	R	5	mg/kg	0.031	A	2
Pentachlorophenol	µg/L	0.03	A	3	µg/L	0.03	A	4					µg/kg	2.5	R	2
Perchlorate					µg/L	15	A	4								
PBDEs													µg/kg	26	R	2
PCBs	µg/L	0.0000064	A	3	µg/L	0.014	A/R	8	µg/kg	9	B	9	µg/kg	0.25 ^b	R	2
PAHs									µg/kg	23000		5				
cPAHs (BaP eq)	µg/L	0.00012	A	3	µg/L	0.00012	A	4	µg/kg	12 ^c	B	1	µg/kg	7.1	R	2
Acenaphthene					µg/L	23	R	8								
Acenaphthylene																
Anthracene					µg/L	0.73	R	8								
Benzo(a)anthracene	µg/L	0.0012	A	3	µg/L	0.0012	A	4								
Benzo(a)pyrene	µg/L	0.00012	A	3	µg/L	0.00012	A	4								
Benzo(b)fluoranthene	µg/L	0.0012	A	3	µg/L	0.0012	A	4								
Benzo(g,h,i)perylene																
Benzo(k)fluoranthene	µg/L	0.0013	A	3	µg/L	0.0013	A	4								
Chrysene	µg/L	0.0013	A	3	µg/L	0.0013	A	4								
Dibenz(a,h)anthracene	µg/L	0.00012	A	3	µg/L	0.00012	A	4								

Table 2
ROD-Identified Cleanup Levels

Contaminant	Surface Water				Groundwater				Riverbank Soil/Sediment				Fish Tissue			
	Unit	Concentration	Basis	RAO	Unit	Concentration	Basis	RAO	Unit	Concentration	Basis	RAO	Unit	Concentration	Basis	RAO
Fluoranthene																
Fluorene																
Indeno(1,2,3-c,d)pyrene	µg/L	0.0012	A	3	µg/L	0.0012	A	4								
2-Methylnaphthalene																
Naphthalene	µg/L	12	R	7												
Phenanthrene																
Pyrene																
Dioxins/Furans (2,3,7,8-TCDD eq)	µg/L	0.0000000005	A	3												
1,2,3,4,7,8-HxCDF									µg/kg	0.0004	B	9	µg/kg	0.00008	R	2
1,2,3,7,8-PeCDD									µg/kg	0.0002	B	9	µg/kg	0.000008	R	2
2,3,4,7,8-PeCDF									µg/kg	0.0003	B	9	µg/kg	0.00003	R	2
2,3,7,8-TCDF									µg/kg	0.00040658	R	9	µg/kg	0.00008	R	2
2,3,7,8-TCDD									µg/kg	0.0002	B	9	µg/kg	0.000008	R	2
Tetrachloroethene					µg/L	0.24	A	4								
Toluene					µg/L	9.8	R	8								
TPH-Diesel									mg/kg	91	R	5				
TPH-Diesel (C10-C12 Aliphatic)					µg/L	2.6	R	8								
Tributyltin	µg/L	0.063	A	7					µg/kg	3080	R	5				
Trichloroethene					µg/L	0.6	A	4								
2,4,5-Trichlorophenol					µg/L	50	A	4								
Vanadium					µg/L	20	R	8								
Vinyl Chloride					µg/L	0.022	A	4								
Xylenes					µg/L	13	R	8								
Zinc	µg/L	36.5	R	7	µg/L	36.5	R	8	mg/kg	459	R	5				

Notes:

a. A/R indicates that the ARARs-based number and the risk-based number are the same.

b. The tissue target is a risk-based number and does not represent background levels. Additional data will be collected to determine background fish tissue concentrations for PCBs during design and construction of the Selected Remedy.

c. Though identified as a background-based cleanup level in the ROD, the cleanup level is equivalent to the risk-based PRG for RAO 1 direct contact to beach sediment. EPA estimated background concentration for cPAH by applying a regression equation to the Total PAH background concentration presented in the RI.

µg/kg: microgram per kilogram

µg/L: microgram per liter

A: ARAR-based number

ARAR: Applicable or Relevant and Appropriate Requirement

B: Background-based number

BEHP: bis(2-ethylhexyl)phthalate

BaP eq: benzo(a)pyrene equivalent

C: carbon

cPAH: carcinogenic polycyclic aromatic hydrocarbon

DDD: dichlorodiphenyldichloroethane

DDE: dichlorodiphenyldichloroethene

DDT: dichlorodiphenyltrichloroethane

DDx: DDD + DDE + DDT

HxCDF: 1,2,3,7,8,9-hexachlorodibenzofuran

MCPP: 2-(4-chloro-2-methylphenoxy)propanoic acid

mg/kg: milligram per kilogram

PAH: polycyclic aromatic hydrocarbon

PBDE: polybrominated diphenyl ether

PCB: polychlorinated biphenyl

PeCDD: pentachlorodibenzo-p-dioxin

PeCDF: pentachlorodibenzofuran

R: risk-based number

RAO: remedial action objective

TCDD: 2,3,7,8-tetrachlorodibenzo-p-dioxin

TCDF: tetrachlorodibenzofurans

TPH: total petroleum hydrocarbons

Table 3
Concentrations of PTW Defined as "Highly Toxic"

Contaminant	Highly Toxic PTW Threshold (µg/kg) (10^{-3} Risk)
PCBs	200
2,3,7,8-TCDD	0.01
2,3,7,8-TCDF	0.6
1,2,3,7,8-PeCDD	0.01
2,3,4,7,8-PeCDF	0.2
1,2,3,4,6,7,8-HxCDF	0.04
DDx	7,050
cPAHs (BaP eq)	106,000

Notes:

µg/kg: microgram per kilogram

cPAH (BaP eq): carcinogenic PAHs (benzo(a)pyrene equivalent)

DDx: dichlorodiphenyldichloroethane + dichlorodiphenyldichloroethene + dichlorodiphenyltrichloroethane

HxCDF: hexachlorodibenzofuran

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyl

PeCDD: pentachlorodibenzo-p-dioxin

PeCDF: pentachlorodibenzofuran

PTW: principal threat waste

TCDD: tetrachlorodibenzo-p-dioxin

TCDF: tetrachlorodibenzofuran

Table 4**Concentrations of PTW Defined as "Reliably Contained"**

Contaminant	PTW Contaminants Reliably Contained
Dioxins/furans	At all concentrations measured at the site
PAHs	At all concentrations measured at the site
Chlorobenzene	At concentrations <320 µg/kg
DDx	At all concentrations measured at the site
Napthalene	At concentrations <140,000 µg/kg
PCBs	At all concentrations measured at the site

Notes:

µg/kg: microgram per kilogram

DDx: dichlorodipenyldichloroethane + dichlorodipenyldichloroethene +dichlorodiphenyltrichloroethane

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyl

PTW: principal threat waste

<: less than

Table 5
Sediment RALs for Selected Remedy

Contaminants	Site-wide RALs (µg/kg)	Navigation Channel RALs (µg/kg)
PCBs	75	1,000
Total PAHs	13,000	170,000
2,3,7,8-TCDD	0.0006	0.002
1,2,3,7,8-PeCDD	0.0008	0.003
2,3,4,7,8-PeCDF	0.2	1
DDx	160	650

Notes:

µg/kg: microgram per kilogram

DDx: dichlorodiphenyldichloroethane + dichlorodiphenyldichloroethene + dichlorodiphenyltrichloroethane

PAH: polycyclic aromatic hydrocarbon

PCB: polychlorinated biphenyl

PeCDD: pentachlorodibenzo-p-dioxin

PeCDF: pentachlorodibenzofuran

RAL: remedial action level

TCDD: tetrachlorodibenzo-p-dioxin

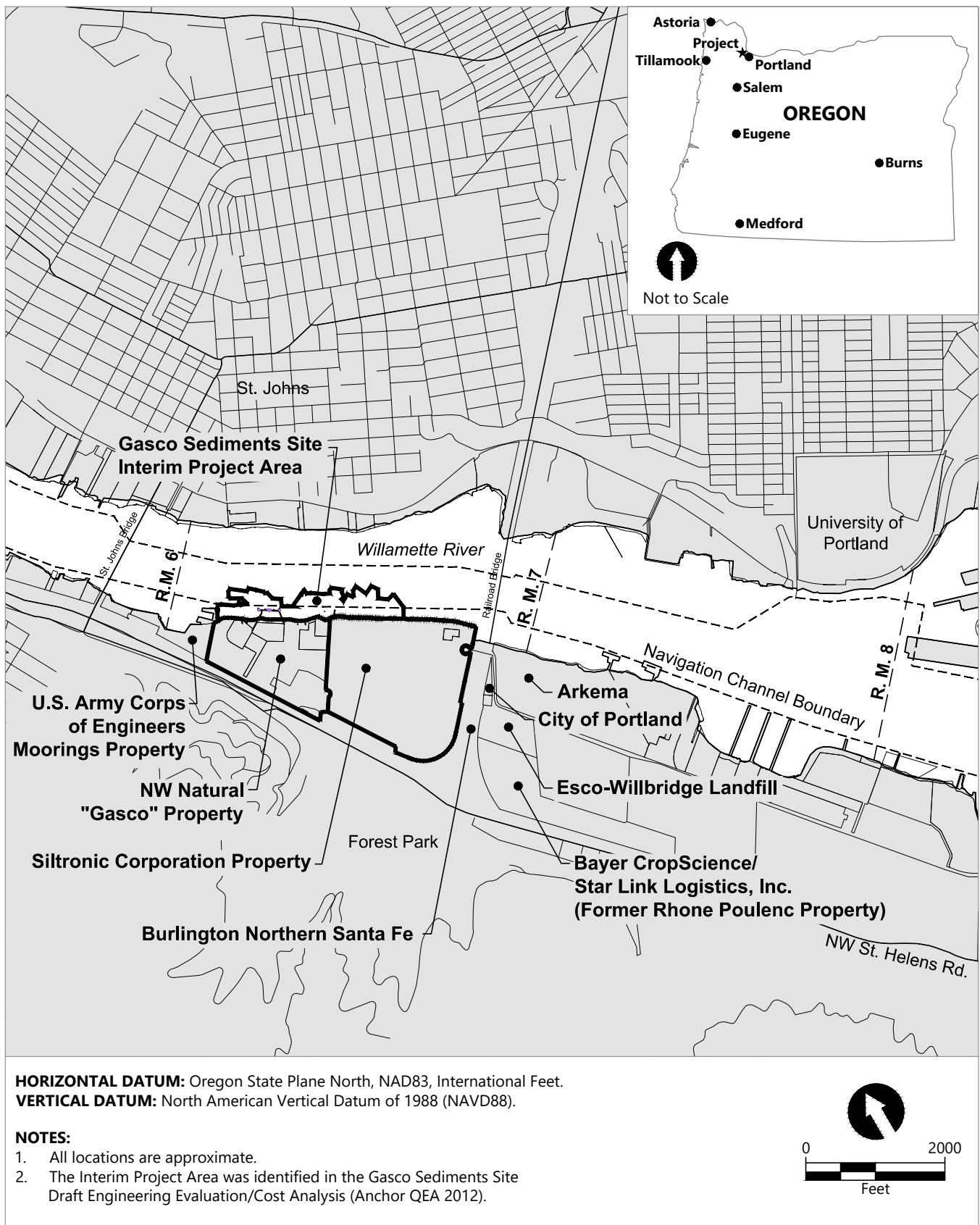
Table 6
Chemical Isolation Cap Modeling Input Parameters

Input Parameters	Units	Contaminant						Data Sources/Notes
		PAHs		VOCs				
		BaP	Naph	Benzene	TCE	DCE	VC	
Contaminant Properties								
Organic Carbon Partition Coefficient, $\log K_{OC}$	log L/kg	6.0	3.30	1.77	2.22	1.77	1.27	Values from USEPA's Soil Screening Guidance (USEPA 1996). Values may be updated with site-specific K_{OC} values based on results from the forthcoming pre-remedial design data gaps sampling.
Water Diffusivity, D_w	cm ² /s	5.33E-06	8.61E-06	1.22E-05	8.46E-06	1.05E-05	1.43E-05	Based on Schwarzenbach (1993) correlation to molecular weight
Cap Decay Rate, l_1	yr ⁻¹	0.00	0.00	0.00	0.00	0.00	0.00	Conservatively assumed no degradation
Bioturbation Layer Decay Rate, l_2	yr ⁻¹	0.00	0.00	0.00	0.00	0.00	0.00	Conservatively assumed no degradation
Colloidal Organic Carbon Partition Coefficient, $\log K_{DOC}$	log L/kg	5.6	2.9	NA	NA	NA	NA	For PAHs, values for K_{DOC} were estimated based on the detailed review published by Burkhard (2000), which tabulated K_{DOC} values from more than 70 studies. K_{DOC} for BaP = 0.2* K_{OC} ; K_{doc} for Naphthalene = 0.5* K_{OC} . Sorption to DOC not simulated for VOCs.
Colloidal Organic Carbon Concentration, r_{DOC}	mg/L	10	10	NA	NA	NA	NA	Based on levels observed in other systems (e.g., O'Brien and Gere Engineers, Inc. 1993; BBL and QEA 2003). This DOC value is in the lower end of the range of values observed at other sites because the water column DOC in the Lower Willamette River is also in the low range compared to other sites. Values may be updated with site-specific r_{doc} values based on results from the forthcoming pre-remedial design data gaps sampling.
Biological Active Zone fraction organic carbon, $(f_{oc})_{bio}$	%	2.0						Average calculated from 0-12" Gasco Sediments Site data
Mass Transport Properties								
Boundary Layer Mass Transfer Coefficient, k_{bl}	cm/hr	0.75						Typical value used for capping design (e.g., Reible 2012)
Depositional Velocity, V_{dep}	cm/yr	0						Assumed no net sedimentation; consistent with EPA ROD (2016)
Bioturbation Layer Thickness, h_{bio}	cm	10						Median value from data compiled for freshwater systems (Reible 2012; adapted from Thoms et al. 1995); typical value for cap design (e.g., Clarke et al. 2001); consistent with EPA ROD (2016)
Porewater Biodiffusion Coefficient, D_{bio}^{pw}	cm ² /yr	100						Parameter represents bioturbation rate applied to dissolved phase; typical value used for capping design (e.g., Reible 2012)
Particle Biodiffusion Coefficient, D_{bio}^p	cm ² /yr	1						Parameter represents bioturbation rate applies to particulate phase; typical value used for capping design (e.g., Reible 2012)
Cap Properties								
Cap Consolidation Depth	cm	0						EPA ROD (2016)
Cap Porosity, e	unitless	0.4						Typical value for sand (e.g., Domenico and Schwartz 1990); consistent with EPA ROD (2016)
Cap Particle Density, ρ_p	g/cm ³	2.65						Typical value for sand (e.g., Domenico and Schwartz 1990); consistent with EPA ROD (2016)
Fraction Organic Carbon of Cap Material, $(f_{oc})_{eff}$	%	0.06						Based on the average f_{oc} of local borrow source material (Morse [0.051 percent] and Scarcella [0.072 percent]). Consistent with EPA ROD (2016)
Underlying Sediment Consolidation	cm	16 cm consolidation for 1 foot cap 24 cm consolidation for 2 foot cap 30 cm consolidation for 3 foot cap						Consolidation of underlying sediment varies with cap thickness. For transient modeling, majority of consolidation assumed to occur within 1 year. For downwelling areas, it is assumed that Gasco property hydraulic control & containment (HC&C) system would counteract porewater migration due to consolidation.
Compliance Criteria								
Water Quality-based Criteria	µg/L	0.00012	12	130	47	590	23400	Anchor QEA 2012 (Appendix Hc); Windward 2011; EPA's RAO 4 or RAO 8 PRG

Notes:
µg: microgram
BaP: benzo(a)pyrene
DCE: cis-1,2-dichloroethene
DOC: dissolved organic carbon
NA: not applicable
Naph: naphthalene

PAH: polycyclic aromatic hydrocarbon
TCE: trichloroethene
USEPA: U.S. Environmental Protection Agency
VC: vinyl chloride
VOC: volatile organic compound

Figures

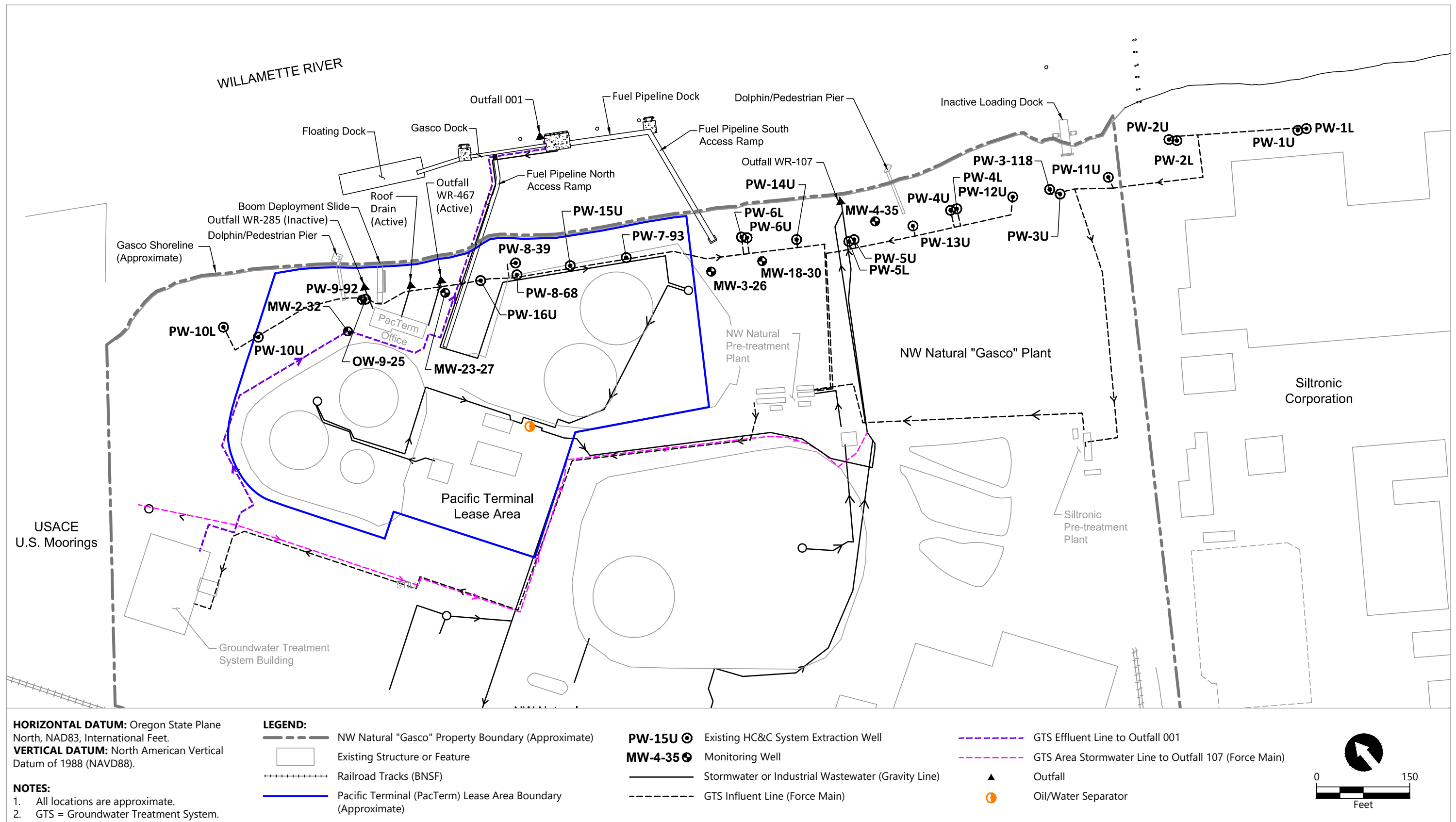


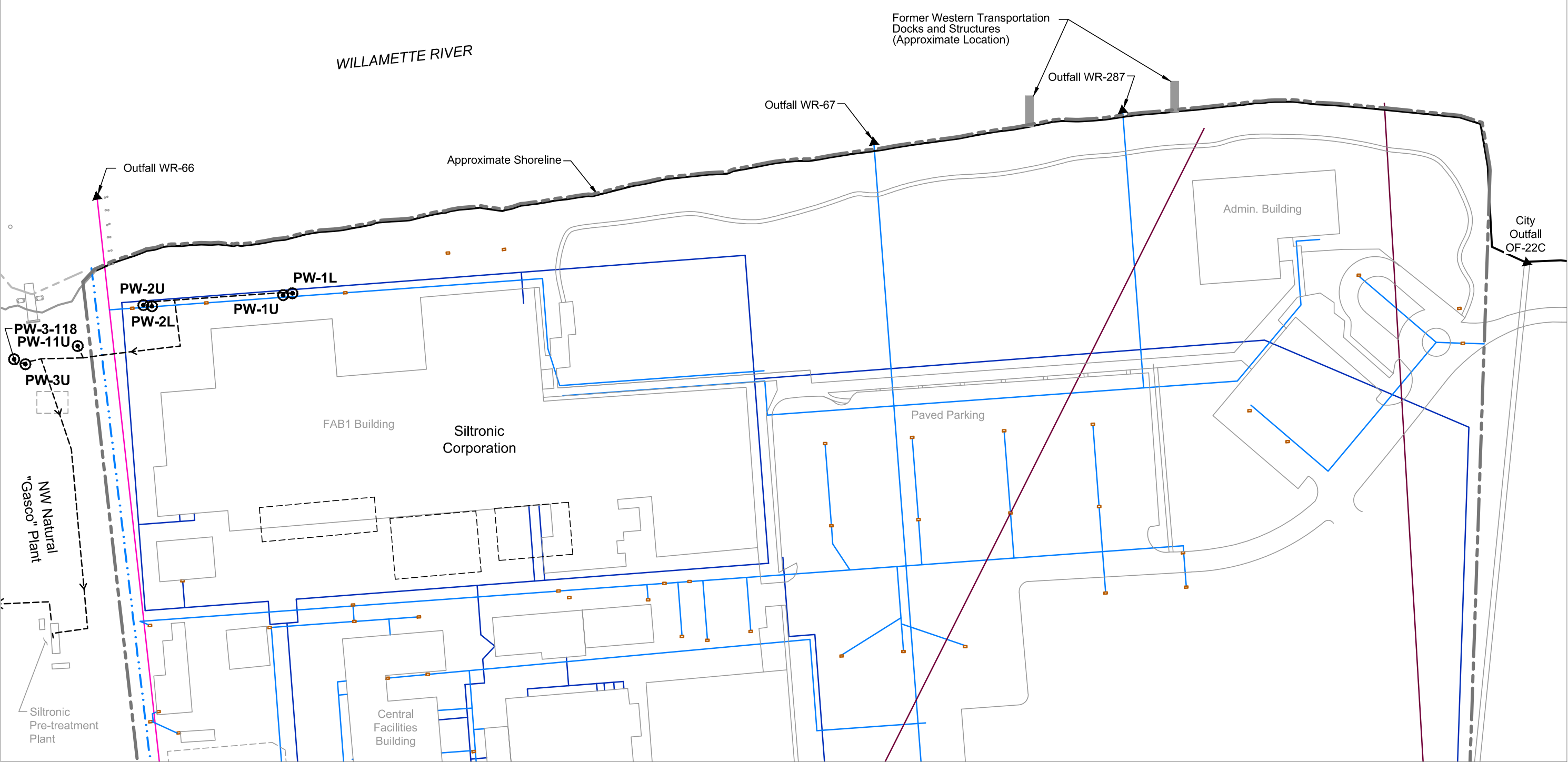
Publish Date: 2017/07/10 4:59 PM | User: dholmer
 Filepath: K:\Projects\0029-NW Natural Gas Co\Gasco Sediments\EECA and Data Report\0029-EECC-004 (Vicinity Map).dwg Site Location



Figure 1
Site Location

Pre-Remedial Basis of Design Technical Evaluations Work Plan
 Gasco Sediments Cleanup Action





HORIZONTAL DATUM: Oregon State Plane North, NAD83, International Feet.
VERTICAL DATUM: North American Vertical Datum of 1988 (NAVD88).

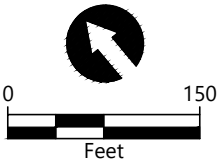
NOTE:
All locations are approximate.

LEGEND:

- Siltronic Property Boundary (Approximate)
- Existing Structure or Feature
- Stormwater Catch Basin
- Combined Stormwater/Process Effluent Sewer Line

- Stormwater Sewer Line
- Abandoned Utility Line
- Source Control Main Pipeline Route

- PW-1L Existing Extraction Well
- ▲ Outfall

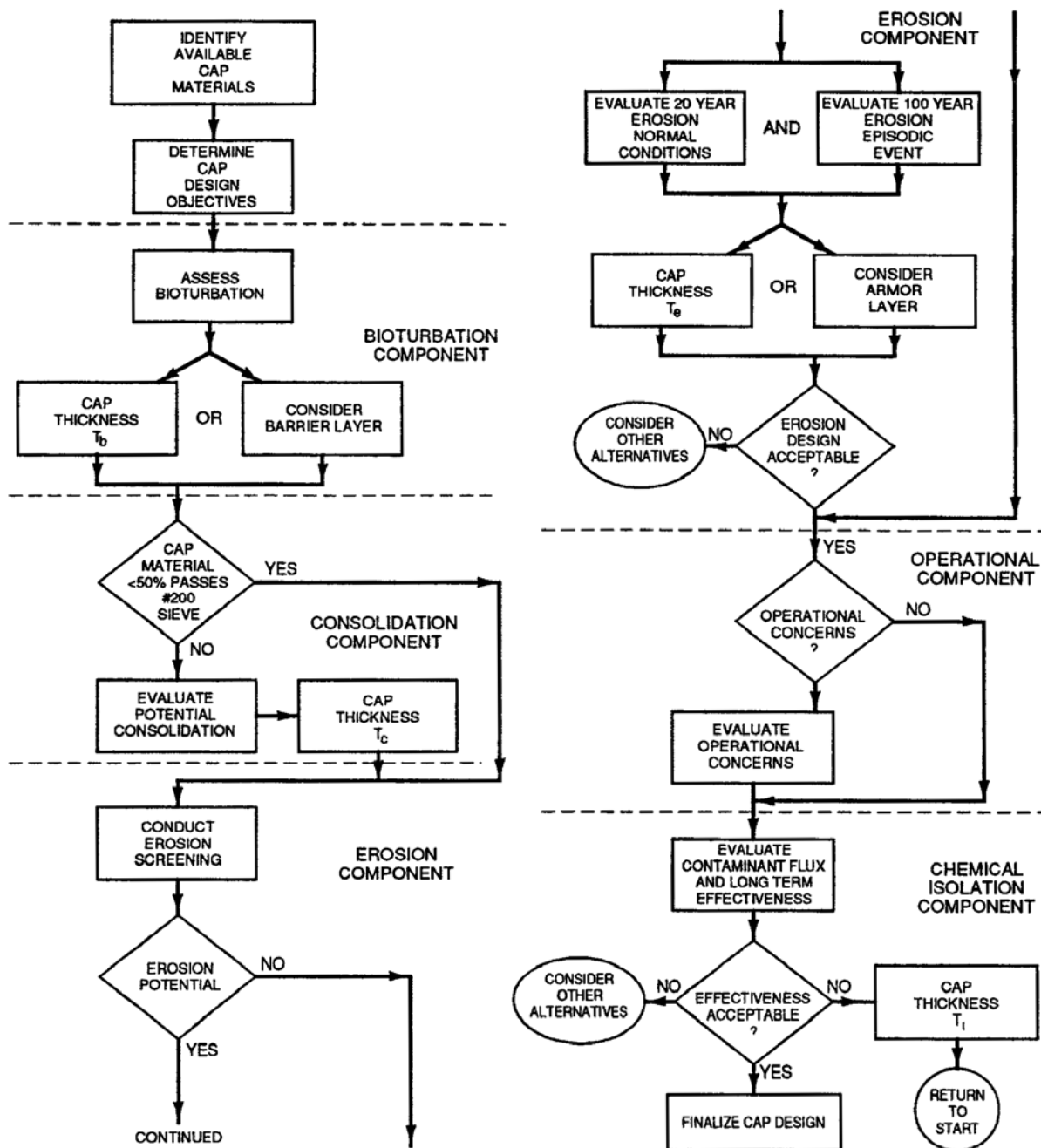


Publish Date: 2017/07/10 4:59 PM | User: dholmer
Filepath: K:\Projects\0029-NW Natural Gas Co\Gasco Sediments\EECA and Data Report\0029-EECC-005.dwg Siltronic Shoreline Structures



Figure 4
Siltronic Shoreline Structures and Upland Source Controls

Pre-Remedial Basis of Design Technical Evaluations Work Plan
Gasco Sediments Cleanup Action

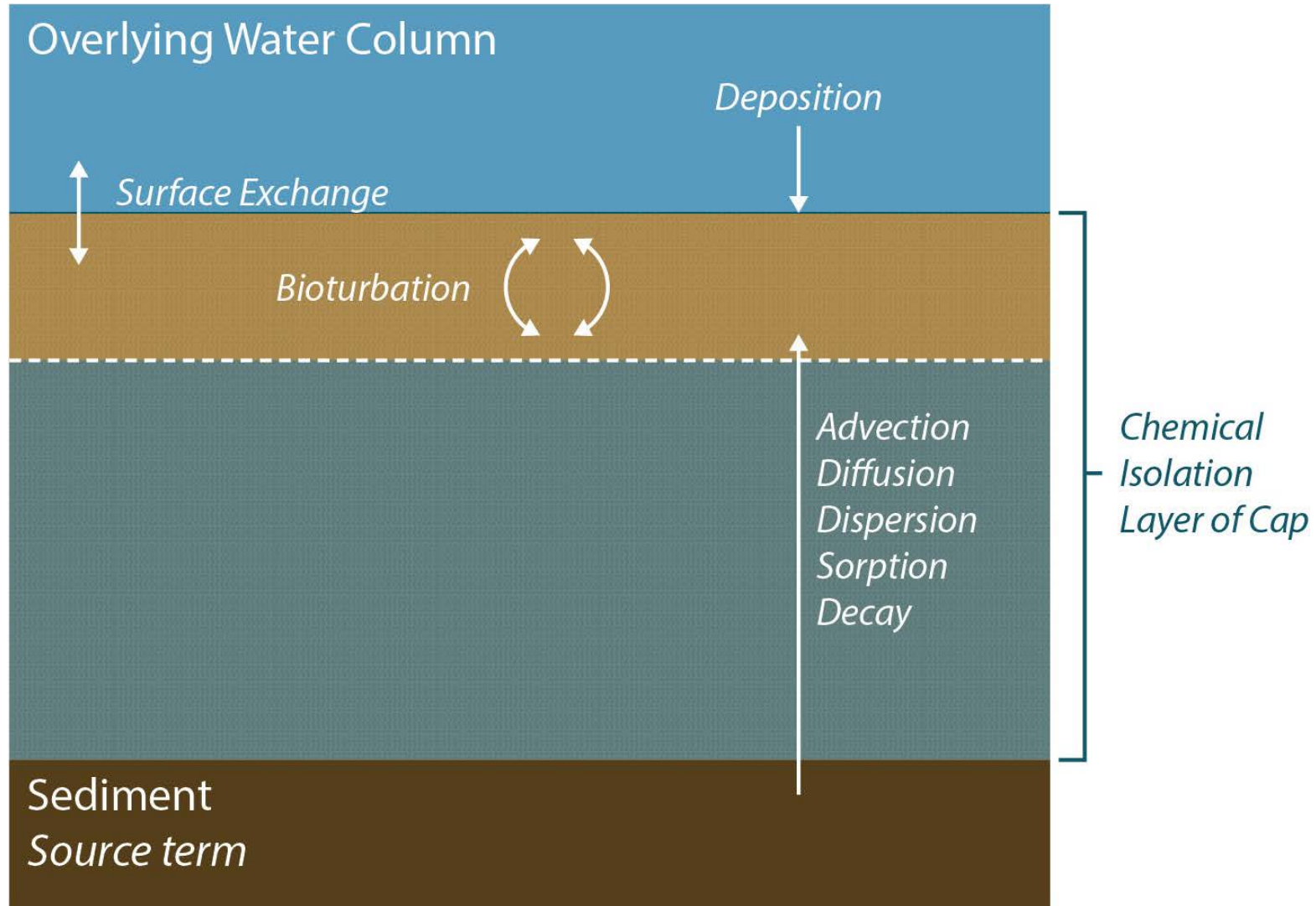


Source: Adapted from Palermo et al. 1998b

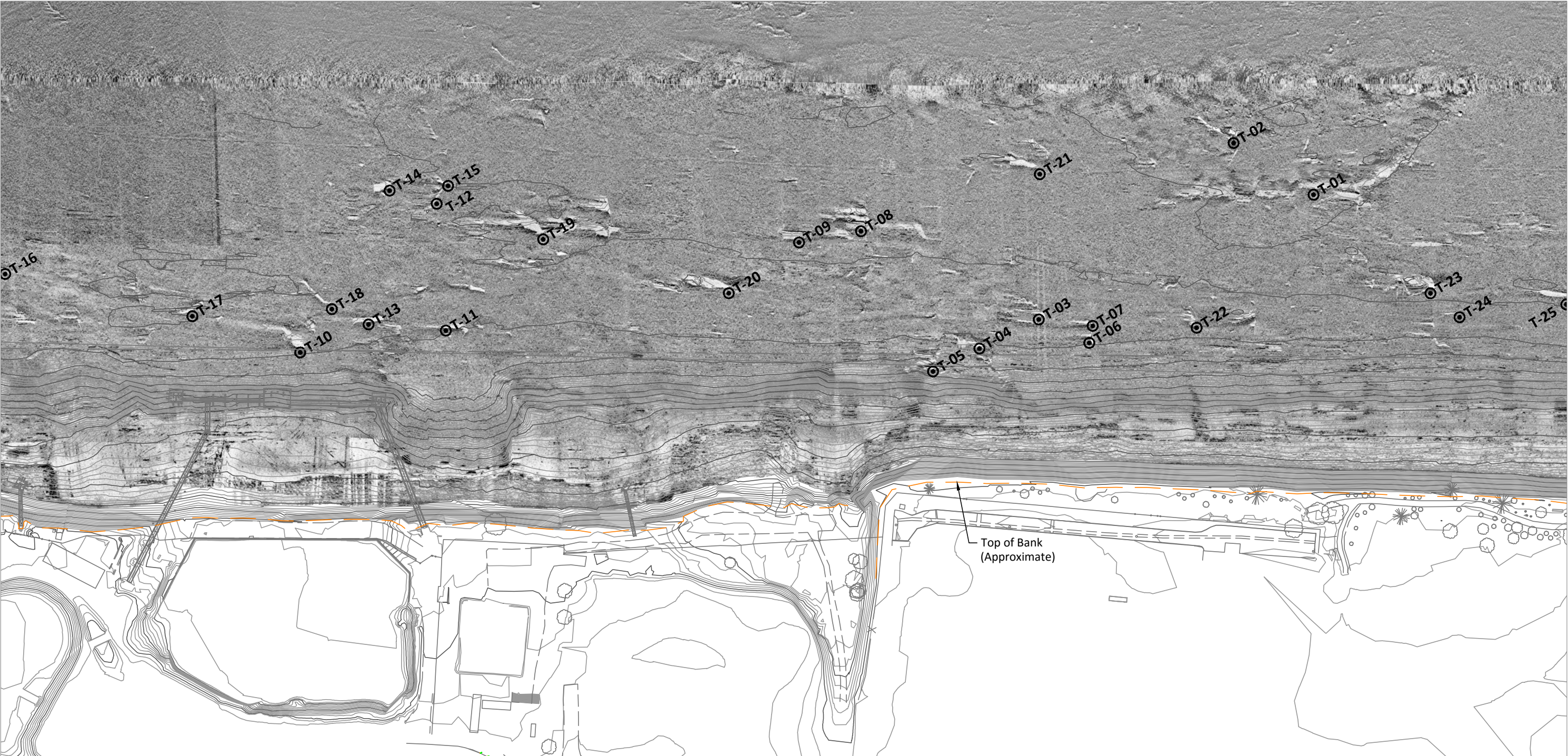
Filepath: I:\Projects\NW Natural\Gasco\Sediments\Sediments New Action\New Early Action Eval\Pre-design Evaluations\Pre-remedial Design Work Plan\1_Figures\Figure 5_EPA Cap Design Flowchart_20170710.docx



Figure 5
EPA Cap Component Design Evaluation Flowchart
 Pre-Remedial Basis of Design Technical Evaluations Work Plan
 Gasco Sediments Cleanup Action

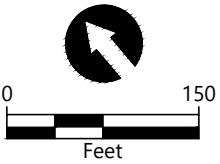


Filepath: I:\Projects\NW Natural\Gasco\Sediments\Sediments New Action\New Early Action Eval\Pre-design Evaluations\Pre-remedial Design Work Plan\1_Figures\Figure 6_Cap Contaminant Transport_20170710.docx



SOURCE: Drawing prepared from side scan sonar survey conducted by Blue Water Engineering dated April 2011.
HORIZONTAL DATUM: Oregon State Plane North, NAD83, International Feet.
VERTICAL DATUM: North American Vertical Datum of 1988 (NAVD88).
NOTES:
1. The interpretation of features was completed by Blue Water Engineering in June 2011.
2. The T-XX features shown on this figure are approximate based on Blue Water Engineering's interpretation of the April 2011 side scan survey data. The presence of these features and/or other debris not shown on this figure should be field verified before using this data for site activities.

T-01	Unknown feature, nominally 350 ft in length.	T-10	Unknown feature, nominally 32 ft in length.	T-19	Unknown feature, nominally 52 ft in length.
T-02	Possible tree bole, nominally 60 ft in length.	T-11	Log, nominally 50 ft in length.	T-20	Unknown feature, nominally 70 ft in length.
T-03	Group of 3 logs, nominally 24 to 34 ft in length.	T-12	Small diameter log, nominally 32 ft in length.	T-21	Log or tree, nominally 67 ft in length.
T-04	Log, nominally 34 ft in length.	T-13	Log, nominally 45 ft in length.	T-22	Possible tree stump, nominally 16 ft across.
T-05	Group of 3-4 logs, nominally 18 to 42 ft in length.	T-14	Medium diameter log, nominally 26 ft in length.	T-23	Unknown feature, nominally 86 ft in length.
T-06	Log, nominally 18 ft in length.	T-15	Small diameter log, nominally 14 ft in length.	T-24	Log, nominally 25 ft in length.
T-07	Log, nominally 22 ft in length.	T-16	Log, nominally 28 ft in length.	T-25	Log, nominally 52 ft in length.
T-08	Group of 4 logs, nominally 25 to 48 ft in length.	T-17	Log, nominally 40 ft in length.		
T-09	Log, nominally 32 ft in length.	T-18	Log, nominally 50 ft in length.		

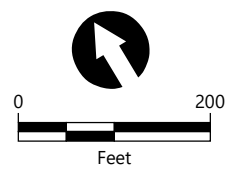




- LEGEND:**
- Soil Sample Location
 - Top of Bank
 - Property Line
 - - - Lease Area Boundaries
 - Navigation Channel

NOTE(S):

1. Acronyms:
EPA = Environmental Protection Agency
DEQ = Oregon Department of Environmental Quality
NAVD88 = North American Vertical Datum 1988
NAD83 = North American Datum 1983
2. Arrow indicates direction of flow of river.
3. Horizontal datum is NAD83 HARN Oregon State Plane North, Intl. Feet.
4. Vertical datum is NAVD88.
5. Aerial imagery from 2014 NAIP.



Publish Date: 2017/07/10, 3:22 PM | User: eiverson
Filepath: \\orcas\GIS\Jobs\NW_Natural_Gas_0029\Gasco_Sediments\Maps\BoD_WorkPlan\AQ_Fig8_RiverbankSamples.mxd



Figure 8
Riverbank Soil Sampling Locations
Pre-Remedial Basis of Design Technical Evaluations Work Plan
Gasco Sediments Cleanup Action

Appendix A

Habitat Equivalency Analysis Workbook

Template

RIPARIAN: Above OHW

OVERALL SUM OF RIPARIAN DSAYS	#DIV/0!
----------------------------------	---------

Description
of Habitat
Change

Pre-Remediation Value of Habitat:

Years to a Fully Functioning Habitat Post-Remediation:

Base Year:

Discount Rate

Years Project Exists:

Value of Remediated Habitat:

Total Increase or Decrease from Remediation:

Acres of Habitat:

SUBTOTAL DSAYs:	#DIV/0!
------------------------	----------------

YEAR	DISCOUNT FACTOR	% INCREASE TOWARDS FULL VALUE	STARTING HABITAT VALUE	ADDITIONAL HABITAT BENEFITS	TOTAL HABITAT VALUE	ACRES OF HABITAT	DISCOUNTED BENEFITS ACRES	SUMMATION OF DSAYS
2017	1.000	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2018	0.971	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2019	0.943	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2020	0.915	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2021	0.888	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2022	0.863	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2023	0.837	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2024	0.813	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2025	0.789	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2026	0.766	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2027	0.744	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2028	0.722	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2029	0.701	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2030	0.681	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2031	0.661	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2032	0.642	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2033	0.623	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2034	0.605	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2035	0.587	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2036	0.570	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2037	0.554	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2038	0.538	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2039	0.522	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2040	0.507	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2041	0.492	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2042	0.478	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2043	0.464	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2044	0.450	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2045	0.437	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2046	0.424	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2047	0.412	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2048	0.400	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2049	0.388	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2050	0.377	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2051	0.366	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2052	0.355	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2053	0.345	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2054	0.335	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2055	0.325	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2056	0.316	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2057	0.307	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2058	0.298	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2059	0.289	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2060	0.281	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2061	0.272	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2062	0.264	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2063	0.257	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2064	0.249	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2065	0.242	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2066	0.235	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2067	0.228	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!

ACM: ACTIVE CHANNEL MARGIN between OHW and OLW

OVERALL SUM OF ACM DSAYS	#DIV/0!
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Description of Habitat	Change riprapped slope to steep bioengineered slope
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Pre-Remediation Value of Habitat:

Years to a Fully Functioning Habitat Post-Remediation:

Base Year: 2017

Discount Rate	0.03
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Years Project Exists: 50

Value of Remediated Habitat:

Total Increase or Decrease from Remediation: 0

Acres of Habitat:

SUBTOTAL DSAYs:	#DIV/0!
------------------------	----------------

		% INCREASE TOWARDS FULL	STARTING HABITAT VALUE	ADDITIONAL HABITAT BENEFITS	TOTAL HABITAT VALUE	ACRES OF HABITAT	DISCOUNTED BENEFITS ACRES	SUMMATION OF DSAYS
YEAR	DISCOUNT FACTOR	VALUE						
2017	1.000	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2018	0.971	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2019	0.943	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2020	0.915	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2021	0.888	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2022	0.863	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2023	0.837	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2024	0.813	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2025	0.789	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2026	0.766	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2027	0.744	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2028	0.722	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2029	0.701	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2030	0.681	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2031	0.661	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2032	0.642	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2033	0.623	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2034	0.605	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2035	0.587	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2036	0.570	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2037	0.554	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2038	0.538	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2039	0.522	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2040	0.507	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2041	0.492	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2042	0.478	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2043	0.464	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2044	0.450	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2045	0.437	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2046	0.424	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2047	0.412	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2048	0.400	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2049	0.388	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2050	0.377	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2051	0.366	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2052	0.355	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2053	0.345	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2054	0.335	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2055	0.325	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2056	0.316	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2057	0.307	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2058	0.298	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2059	0.289	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2060	0.281	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2061	0.272	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2062	0.264	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2063	0.257	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2064	0.249	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2065	0.242	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2066	0.235	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2067	0.228	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!

SHALLOW WATER: 0 TO 10 FEET BELOW OLV LEVEL

OVERALL SUM OF SHALLOW WATER DSAYS	#DIV/0!
---------------------------------------	---------

Description
of Habitat
Change

Pre-Remediation Value of Habitat:

Years to a Fully Functioning Habitat Post-Remediation:

Base Year:

Discount Rate

Years Project Exists:

Value of Remediated Habitat:

Total Increase or Decrease from Remediation:

Acres of Habitat:

SUBTOTAL DSAYs:	#DIV/0!
------------------------	----------------

		% INCREASE TOWARDS FULL	STARTING HABITAT VALUE	ADDITIONAL HABITAT BENEFITS	TOTAL HABITAT VALUE	ACRES OF HABITAT	DISCOUNTED BENEFITS ACRES	SUMMATION OF DSAYS
YEAR	DISCOUNT FACTOR	VALUE						
2017	1.000	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2018	0.971	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2019	0.943	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2020	0.915	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2021	0.888	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2022	0.863	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2023	0.837	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2024	0.813	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2025	0.789	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2026	0.766	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2027	0.744	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2028	0.722	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2029	0.701	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2030	0.681	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2031	0.661	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2032	0.642	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2033	0.623	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2034	0.605	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2035	0.587	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2036	0.570	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2037	0.554	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2038	0.538	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2039	0.522	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2040	0.507	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2041	0.492	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2042	0.478	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2043	0.464	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2044	0.450	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2045	0.437	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2046	0.424	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2047	0.412	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2048	0.400	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2049	0.388	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2050	0.377	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2051	0.366	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2052	0.355	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2053	0.345	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2054	0.335	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2055	0.325	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2056	0.316	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2057	0.307	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2058	0.298	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2059	0.289	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2060	0.281	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2061	0.272	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2062	0.264	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2063	0.257	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2064	0.249	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2065	0.242	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2066	0.235	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2067	0.228	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
		#DIV/0!					#DIV/0!	

SHALLOW WATER: 10 TO 20 FEET BELOW OLW LEVEL

OVERALL SUM OF SHALLOW WATER DSAYS	#DIV/0!
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Description
of Habitat
Change

Pre-Remediation Value of Habitat:

Years to a Fully Functioning Habitat Post-Remediation:

Base Year:

Discount Rate

Years Project Exists:

Value of Remediated Habitat:

Total Increase or Decrease from Remediation:

Acres of Habitat:

SUBTOTAL DSAYs:	#DIV/0!
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YEAR	DISCOUNT FACTOR	% INCREASE TOWARDS FULL VALUE	STARTING HABITAT VALUE	ADDITIONAL HABITAT BENEFITS	TOTAL HABITAT VALUE	ACRES OF HABITAT	DISCOUNTED BENEFITS ACRES	SUMMATION OF DSAYS
2017	1.000	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2018	0.971	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2019	0.943	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2020	0.915	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2021	0.888	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2022	0.863	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2023	0.837	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2024	0.813	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2025	0.789	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2026	0.766	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2027	0.744	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2028	0.722	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2029	0.701	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2030	0.681	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2031	0.661	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2032	0.642	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2033	0.623	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2034	0.605	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2035	0.587	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2036	0.570	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2037	0.554	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2038	0.538	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2039	0.522	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2040	0.507	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2041	0.492	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2042	0.478	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2043	0.464	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2044	0.450	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2045	0.437	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2046	0.424	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2047	0.412	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2048	0.400	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2049	0.388	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2050	0.377	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2051	0.366	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2052	0.355	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2053	0.345	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2054	0.335	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2055	0.325	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2056	0.316	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2057	0.307	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2058	0.298	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2059	0.289	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2060	0.281	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2061	0.272	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2062	0.264	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2063	0.257	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2064	0.249	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2065	0.242	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2066	0.235	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2067	0.228	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!

DEEP WATER: Deeper than 20 FEET BELOW OLVW LEVEL

OVERALL SUM OF DEEP WATER DSAYS	#DIV/0!
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Description
of Habitat
Change

Pre-Remediation Value of Habitat:

Years to a Fully Functioning Habitat Post-Remediation:

Base Year:

Discount Rate

Years Project Exists:

Value of Remediated Habitat:

Total Increase or Decrease from Remediation:

Acres of Habitat:

SUBTOTAL DSAYs:	#DIV/0!
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YEAR	DISCOUNT FACTOR	% INCREASE TOWARDS FULL	STARTING HABITAT	ADDITIONAL HABITAT	TOTAL HABITAT	ACRES OF HABITAT	DISCOUNTED BENEFITS ACRES	SUMMATION OF DSAYS
		VALUE	VALUE	BENEFITS	VALUE			
2017	1.000	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2018	0.971	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2019	0.943	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2020	0.915	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2021	0.888	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2022	0.863	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2023	0.837	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2024	0.813	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2025	0.789	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2026	0.766	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2027	0.744	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2028	0.722	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2029	0.701	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2030	0.681	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2031	0.661	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2032	0.642	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2033	0.623	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2034	0.605	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2035	0.587	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2036	0.570	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2037	0.554	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2038	0.538	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2039	0.522	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2040	0.507	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2041	0.492	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2042	0.478	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2043	0.464	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2044	0.450	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2045	0.437	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2046	0.424	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2047	0.412	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2048	0.400	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2049	0.388	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2050	0.377	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2051	0.366	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2052	0.355	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2053	0.345	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2054	0.335	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2055	0.325	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2056	0.316	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2057	0.307	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2058	0.298	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2059	0.289	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2060	0.281	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2061	0.272	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2062	0.264	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2063	0.257	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2064	0.249	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2065	0.242	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2066	0.235	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
2067	0.228	#DIV/0!	0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!
		#DIV/0!					#DIV/0!	

OVERALL SUMMARY FOR GASCO SITE

HABITAT ZONE	ELEVATION	DSAYs Post Remediation
Riparian	Above OHW	#DIV/0!
ACM	OHW to OLW	#DIV/0!
Shallow Water	0 to 10 ft below OLW	#DIV/0!
Shallow Water	10 to 20 ft below OLW	#DIV/0!
Deep Water	Greater than 20 ft below OLW	#DIV/0!
Habitat Conversions		#DIV/0!
	Overall Site Total of DSAYs	#DIV/0!

(negative number indicates habitat deficit and requirement for mitigation; positive number indicates habitat benefit)

Appendix B

Portland Harbor Natural Resource Trustee Council and NMFS Relative Habitat Values

Draft HEA Habitat Values for ESA Consultation			
Habitat	Habitat Characteristics	Yrs Until Full Function	Salmonid Value
Riparian	naturally vegetated forest, <400 ft from ACM ¹	40 ²	0.5
	and in the historic floodplain	40 ²	0.65
	naturally vegetated, grass/shrub	5	0.2
	and associated with historic floodplain	5	0.35
	invasive species ³	3	0.1
	vegetated riprap	NA	0.05
	unvegetated/paved/buildings/riprap	NA	0
Active channel margin	sloped (<5:1 or 11°), unarmored and vegetated ⁴	3	1
	sloped (>5:1 or 11°), unarmored and vegetated ⁴	3	0.8
	sloped (<5:1), unarmored and unvegetated	3	0.8
	sloped (>5:1), unarmored and unvegetated	1	0.1
	sloped (<5:1), bio-engineered	3	0.2
	sloped (>5:1), bio-engineered	3	0.2
	riprapped	NA	0
	sheetpile	NA	0
	pilings	NA	1/2 value of margin type
	covered structures over channel margins ⁵	NA	0.1
Main channel	shallow water, gravel and finer substrates	1	1 (0.9)
	shallow water, natural rock outcrop ⁶	NA	1 (0.9)
	shallow water with riprap or concrete	NA	0.1 (0.1)
	shallow water with covering structures ⁵	NA	0.1 (0.1)
	shallow water with pilings	NA	1/2 value of channel type
	deep water with natural substrates	1	0.1
	deep water with artificial substrates	NA	0.05
Off channel	"cold" water tributary	1	1
	"warm" water tributary	1	0.9
	side channel	1	1
	alcove or slough with tributary	1	1 ⁷
	alcove or slough without tributary	1	0.8
	embayment (cove) with tributary	1	1 ⁷
	embayment (cove) without tributary	1	0.8 ⁸

¹ ACM = active channel margin

² achieves 80% of full function within 10 years; this time is adequate because of flood protection

³ eg. Himalayan blackberry

⁴ native species, value is 1/2 the value listed if vegetated with invasive species

⁵ eg. docks

⁶ cannot be created

⁷ value is 0.9 for salmonid adults if "warm" water tributary

⁸ value is around 0.6 further upstream

Notes:

- The listed habitat values are for Portland Harbor. Areas outside Portland Harbor may have different values for some species, or no value for some species. In such cases, multiple projects may be needed to fully mitigate for the effects of an action on all species affected.
- Debits and credits for a given project need to come from the same habitat category (eg. main channel), unless credits come from creating off channel habitat because it is a primary limiting factor for salmonids.
- No credit will be given for creating any new habitat with riprap, artificial substrates, pilings or covering structures.
- Credit for simply removing pilings is limited to 0.1 and for removing covering structures is limited to 0.5.
- For ESA purposes, shallow water habitat is defined as <20 feet of water depth as measured at the ordinary low water level. The value listed in the table is for shallow water habitat 0-10 feet in depth and the value in parentheses next to it is for shallow water habitat 10-20 feet in depth.
- Bio-engineering is defined as the use of living and nonliving plant materials in combination with natural and synthetic support materials for slope stabilization, erosion reduction, and vegetative establishment. To receive credit for bio-engineered ACM, the treatments may include inert components and grading but they must fundamentally rely on riparian plants to provide long term strength to the bank. Inert material may be used but generally only to temporarily reduce hydraulic pressures so that the planted live material can become established. NMFS must approve any proposal for bio-engineered ACM for credit to be given.

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Portland Harbor Natural Resource Trustee Council
“Expert Panel” Discussion of Habitat Restoration for Chinook Salmon

Executive Summary

On November 30 and December 1, 2009, a panel of experts was convened by the Portland Harbor Natural Resource Trustee Council to develop a scientific foundation for restoration planning being conducted under the Natural Resource Damage and Assessment program (NRDA) for the Portland Harbor Superfund site. The Trustees have been engaged in the early phases of restoration planning since 2007, and have developed some preliminary approaches and priorities for restoration of natural resources and habitats that may have been injured by releases of hazardous substances in Portland Harbor. Before moving into a more formal phase of restoration planning and closer to settlements with Potentially Responsible Parties (PRPs), the Trustees paused to invite the review and input of recognized experts on salmon and salmon habitat in the Lower Willamette River, in order to identify a scientific framework and priorities to guide the development of a restoration plan.

The purposes of the two-day expert panel session were to:

- identify the most relevant scientific literature and technical resources to guide restoration planning;
- understand the primary habitat requirements and limiting factors for juvenile Chinook salmon in the Lower Willamette River; and
- identify the types, characteristics and geographic locations of habitat restoration actions that would provide the greatest benefit for juvenile Chinook salmon.

The expert panel was comprised of the following members:

- Tom Friesen, Fish Biologist, Oregon Department of Fish and Wildlife’s Corvallis Research Lab
- Stan Gregory, PhD, Professor of Fisheries, Oregon State University
- Nancy Munn, PhD, Aquatic Ecologist and Policy Analyst, National Marine Fisheries Service, Habitat Division
- Chris Prescott, Watershed Ecologist, City of Portland’s Bureau of Environmental Services

Other participants included:

- Charles “Pete” Peterson, PhD, Interdisciplinary Marine Conservation Ecologist, University of North Carolina

- Erin Madden, Chair, Portland Harbor Natural Resource Trustee Council, representative of Nez Perce Tribe
- Robert Wolotira, NOAA Restoration Center, Habitat Equivalency Analyst
- Megan Callahan Grant, NOAA Restoration Center, Restoration Planning Coordinator for Portland Harbor Natural Resource Trustee Council (facilitator)
- Megan Hilgart, NOAA Restoration Center (recorder)

Erin Madden provided an overview of the Portland Harbor Natural Resource Trustee Council, its authorities under CERCLA and NRDA, and its phased plan for making the public whole for losses of natural resources, habitats and services in Portland Harbor. Nancy Munn presented background information on Endangered Species Act listings of salmonids that utilize habitat in the Harbor area, and factors that have been identified as limiting recovery of these species. Robert Wolotira provided an overview of Habitat Equivalency Analysis, using a Puget Sound site as an example. Tom Friesen described the findings of his research on juvenile Chinook diet and habitat utilization in the Lower Willamette River. Stan Gregory and Chris Prescott provided relevant information on their biological and ecological research and monitoring of the Upper and Lower Willamette River.

The expert panel reached consensus in the following areas:

1. Juvenile Chinook salmon utilize the Lower Willamette River for feeding and rearing before entering the Columbia River Estuary to a greater extent than previously believed. Chinook salmon are present almost year-round in the Lower Willamette.
2. Both yearling and subyearling (young-of-the-year) juvenile Chinook are found in the Lower Willamette. Although migration rates for subyearlings have not been directly evaluated, studies have shown that Chinook migration rate increases with fish size. Therefore, subyearlings may spend more substantial amounts of time than yearlings (more than two weeks) feeding and developing in the lower Willamette.
3. The area of the Lower Willamette that is most important for juvenile Chinook extends from Willamette Falls to the mouth of the Willamette (the broadest definition of the mouth or confluence with the Columbia includes the Lower Columbia mainstem from the Sandy River confluence upstream to the Lewis River confluence downstream), including the confluence areas of the major tributaries (Clackamas, Johnson, Kellogg and Tryon creeks), and Multnomah Channel.

4. The most limited or scarce habitat types within this area include any refuge from mainstem Willamette flows (alcoves and off-channel habitats, tributary mouths); shallow water and beach habitats with or without large wood assemblages; and undulating, natural shorelines. Other important potential limiting factors include temperature and toxics, as well competition and predation by non-native species that are more tolerant of high temperatures and toxics.
5. The extreme scarcity of key habitat types within the Portland Harbor study area (RM 1-11.8) makes it the expert panel's highest priority for restoration actions. Additional justification for this priority was provided by the panel
 - The study area contains the most impaired habitat in the river; the river is almost completely disconnected from its floodplain in this reach, with many ecosystem processes severely impaired. Further, physical alterations to the channel's edge severely limit availability of nearshore shallow water habitats.
 - The Lower Willamette is the first (lowermost) major tributary junction in the Columbia River basin.
 - A significant number of threatened and endangered (Columbia River and Willamette River) species use the area; all Willamette River stocks must pass through the study area twice during their life cycle.
 - The area's history of toxic contamination poses growth and survival challenges for juvenile salmonids, reducing their resiliency to other stressors.
 - The Lower Willamette contains the largest number of invasive/non-native species in the Willamette system, posing a further survival challenge to native salmonids.
 - There is an important opportunity for public education and outreach in the urban area.
 - Habitats within the study area are underserved by existing, non-NRDA sources of funding for restoration, compared to the mainstem Lower Columbia River, and tributaries such as the Clackamas River.
6. The expert panel developed a set of values for existing and potentially restorable types of habitat. The habitat types were evaluated based on their relative importance to juvenile Chinook, with the most important habitat types valued at 1.0, and all other habitat types valued relative to those "ideal" habitat types. These values will be used by the Trustees to identify the current, as well as potential future, value of specific habitats at specific locations as part of the Habitat Equivalency Analysis (HEA) model, and to calculate the increased habitat value or "lift" generated by restoration projects. The table of HEA values generated by the expert panel is attached to this summary.

7. The expert panel identified several characteristics that could increase the value of a restoration project. These include:
- Restoration actions that would result in high quality habitat along both banks of a stretch of river
 - Projects that provide off-channel habitats or flow refuges at regular intervals ("stepping stones"), especially along the same side of the river
 - Restoration actions that provide a connection to a cold water tributary
 - Projects that provide cumulative ecosystem services (carbon sequestration, non-structural flood storage, wetland, wildlife benefits)
 - Projects of substantial size (expert panel noted that these are rare within the study area) so that ecosystem functions and processes are able to maintain habitats with minimal human manipulation or maintenance
 - Projects that restore multiple functional habitat types
 - Projects that protect existing, high-quality habitats
 - Projects that reconnect portions of the historic flood plain

Recommendations:

The expert panel recommended a strong emphasis on restoration of habitats within the Portland Harbor study area, but also noted the importance of habitats upstream and downstream of the study area. For upstream habitats (upstream of the study area to Willamette Falls), the panel recommended a focus on protecting intact habitats along the mainstem Willamette and tributary mouths that are currently developable and in private ownership. For downstream habitats (Multnomah Channel and Willamette River mouth and environs), the focus should be restoration of forested, complex and undulating shorelines, and the restoration of off-channel habitats.

Although the panel developed a table of initial relative values for each existing and potentially restorable habitat type (for habitat equivalency analysis), the panel members recommended that the Trustees contract out for an independent literature review, and that values be adjusted based on the results of that review.

The panel suggested that Potentially Responsible Parties should be required to direct a minimum of one third to one half of their total liability to restoration projects inside the study area. The panelists identified conservation banking as one possible mechanism to ensure timely and efficient implementation of high-priority restoration actions. The panel also stressed the importance of long-term monitoring, management and stewardship of restoration projects in order to ensure the highest possible degree of

scientific learning and the greatest chance of success, and encouraged the Trustees to account for these functions when estimating cost and value of restoration actions.

Table 1. Relative Chinook Salmon Lower Willamette Habitat Values

Habitat	Habitat Characteristics	Function Hab. Val	Yrs Until Full Function
Upland	forested, in hist. floodplain, >200 ft from ACM*	0.65	50
	forested, outside historic floodplain	0.15	40 (80% in 10 yrs)
	vegetated, grass/shrub outside floodplain	0.1	5
	vegetated, invasive spp. outside floodplain	0.05	--
	forested along tributary into Willamette	0.15	40
	forested and part of the historic floodplain	0.3	40
	vegetated, grass/shrub in historic floodplain	0.2	5
	vegetated, invasive spp in historic floodplain	0.1	--
	unvegetated/paved/buildings	0	--
Riparian	naturally vegetated forest, <200 ft from ACM and in the historic floodplain	0.5	40** (80% in 10 yrs)
		0.65	50
	naturally vegetated, grass/shrub	0.2	5
	and associated with historic flood plain	0.35	5
	invasive species	0.1	3
Active channel margin	Sloped (<5:1 or 11°), unarmored and vegetated	1	3
	Sloped (>5:1 or 11°), unarmored and vegetated	0.2	3
	sloped (<5:1), unarmored and unvegetated	0.8	3
	sloped (<5:1), bio-engineered	0.4	3
	sloped (>5:1), bio-engineered	0.2	3
	riprapped	0.1	1
	sheetpile	0	--
	pilings (1 per 100 sq ft)	half value of margin type	
	covered structures over channel margins	max of 0.1	--
Main Channel	shallow water, gravel and finer substrates	1	1
	shallow water, natural rock outcrop	1	1
	shallow water with riprap or concrete	0.1	1
	shallow water with covering structures	0.1	--
	shallow water with pilings (1 per 100 sq ft)	0.5	1
	deep water with natural substrates	0.1	1
	deep water with artificial substrates	0.05	1
Off Channel	"Cold" water tributary	1	1
	"Warm" water tributary	0.9	1
	side channel	1	1
	alcove or slough with tributary	1	1
	alcove or slough without tributary	0.8	1
	embayment (cove) with tributary	1	1
	embayment (cove) without tributary	0.8***	1

*--ACM = Active Channel Margin

**--this time adequate for juvenile chinook because of flood protection.

***--around 0.6 further upstream